WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

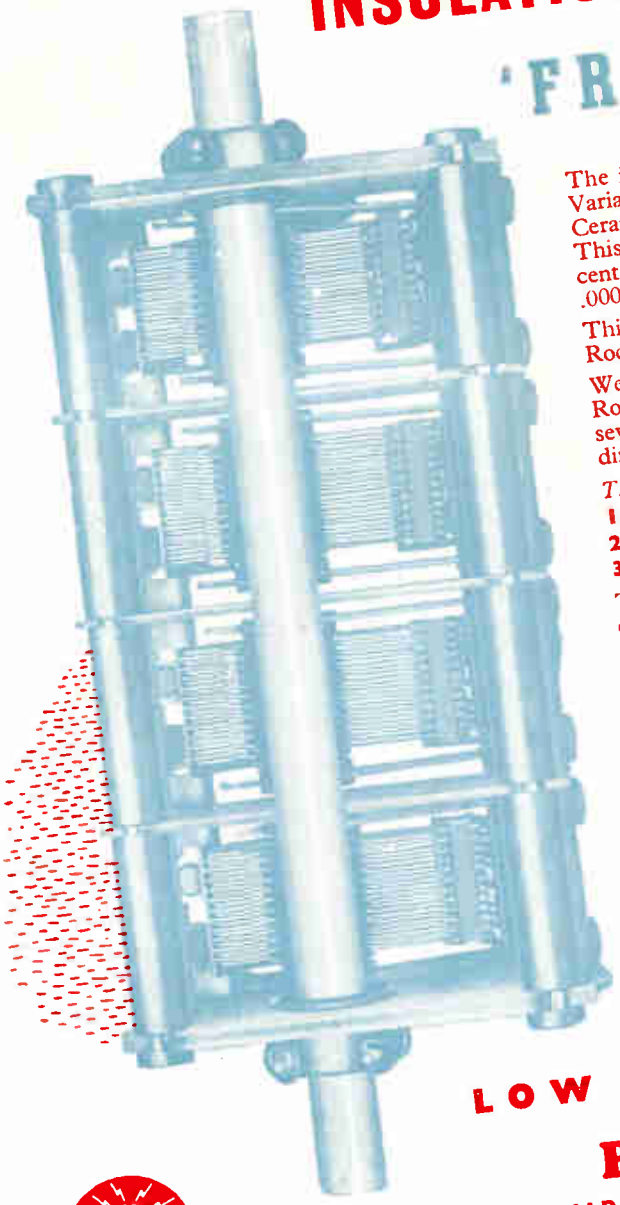
MARCH 1954

VOL. 31 No. 3 SIX SHILLINGS

Including Index to Vol. 30 and Index to Abstracts 1953
(formerly published separately)

World Radio History

FOR HIGH-FREQUENCY INSULATION—specify 'FREQUELEX'



The illustration shows a Four Gang Radio Variable Condenser using our "FREQUELEX" Ceramic Rod for the Centre Rotating Spindle. This Rod is 7½" long × .437" diameter, centreless ground to within plus or minus .0005". Maximum camber allowance of .002".

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3. **Permalex and Templex for Capacitors.**

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Reg'd Trade Mark

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Type 100-R 'VARIAC'

SERIES 50 'VARIAC' TRANSFORMERS.

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Type	Load Rating	Input Voltage	Current		Output Voltage	No-Load Loss	Net Price £ s. d.*
			Rated	Maximum			
50-A	5 kva.	115 v.	40 a.	45 a.	0-135 v.	65 watts	44 18 6
50-B	7 kva.	230/115 v.	20 a.	31 a.	0-270 v.	90 watts	44 18 6

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OC10 OC11 OC12 — 3 JUNCTION TRANSISTORS for circuit experiments

Three types of junction transistor, the Mullard OC10, OC11 and OC12 are now available for circuit experiments.

In the past, the lack of supplies has prevented circuit designers in this country from gaining direct experience of junction transistors in their own laboratories. Now, however, the availability of the first junction types invites practical investigation into their many possible applications.

As junction transistors provide no current gain when connected with grounded base, they are more usually employed in grounded emitter circuits, where they function well as A.F. amplifiers. In both amplifier and oscillator circuits these transistors will operate with supply voltages as low as 1.5 V and with current consumptions of the same remarkably low order.

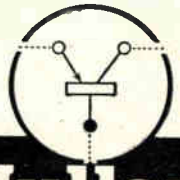
The OC11 is a general-purpose amplifier, while the OC12 is intended for operation in an output stage, although it can, of course, be used otherwise. A low-noise version of the OC11 is provided by the OC10, a special transistor for early stages in high-gain amplifiers.

Junction transistor type		OC10	OC11	OC12
Max. D.C. negative collector-to-emitter voltage	(V)	4	4	4
Typical D.C collector voltage	(V)	2	2	2
Typical collector current	(mA)	−0.5	−0.5	−2
Current amplification factor (α') with grounded emitter		17	17	30
Output resistance with infinite A.C. source impedance (grounded base)	(KΩ)	700	700	500
Special low-noise characteristics		★	—	—

★ Superior type for these characteristics.

Information on these junction transistors and the point-contact types in the Mullard range of semi-conducting devices will be gladly supplied by the Industrial Technical Service Department at the address below.

● The OC10, OC11 and OC12 are readily available for experimental purposes at a price comparable with that of mains subminiature valves.



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MVT152

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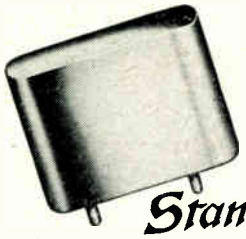

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Broad-band Matching

The photograph shows Marconi engineers erecting for test the three-stack super-turnstile TV aerial for the new B.B.C. transmitter at Pontop Pike. Wayne Kerr Bridges are used for matching feeders and transmission lines to the radiators.

FOR UNBALANCED MEASUREMENT FROM 50—250 MC/S

B.901

Susceptance: *Equivalent to ± 75 pF to ± 2%, ± 0.5 pF*
Conductance: *0-100 mmho to ± 2%, ± 0.1 mmho*

FOR BALANCED AND UNBALANCED MEASUREMENT FROM 1—100 MC/S

B.801 and B.701

Susceptance: *Equivalent to ± 230 pF to ± 2%, ± 0.5 pF*
Conductance: *0-100 mmho to ± 2%, ± 0.1 mmho*
Susceptance: *Equivalent to ± 80 pF to ± 2%, ± 0.5 pF*
Conductance: *0-100 mmho to ± 2%, ± 0.02 mmho*

FOR BALANCED AND UNBALANCED MEASUREMENT FROM 15 KC/S—5 MC/S

B.601

Capacitance: *0.01 pF — 20,000 pF*
Resistance: *10 ohms — 10 megohms*
Inductance: *0.5 μH — 50 mH*
Accuracy: *1% over major part of range*

These Wayne Kerr Bridges are used with external source and detector for the measurement of aerials, cables, feeders, and a variety of components and materials.

Photograph by courtesy of Marconi's Wireless Telegraph Co. Ltd.

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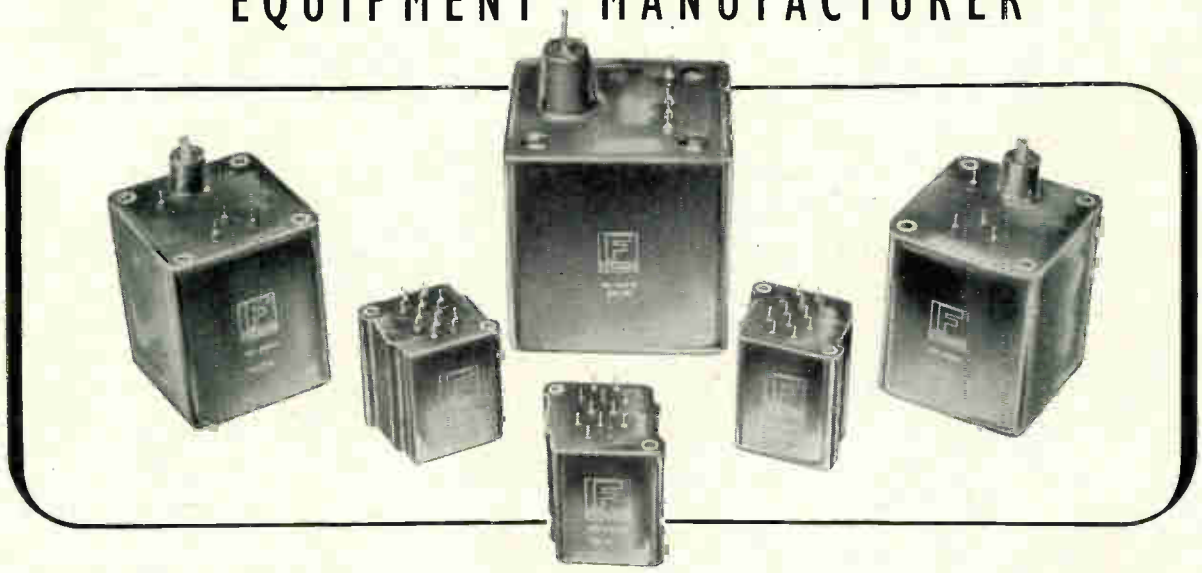

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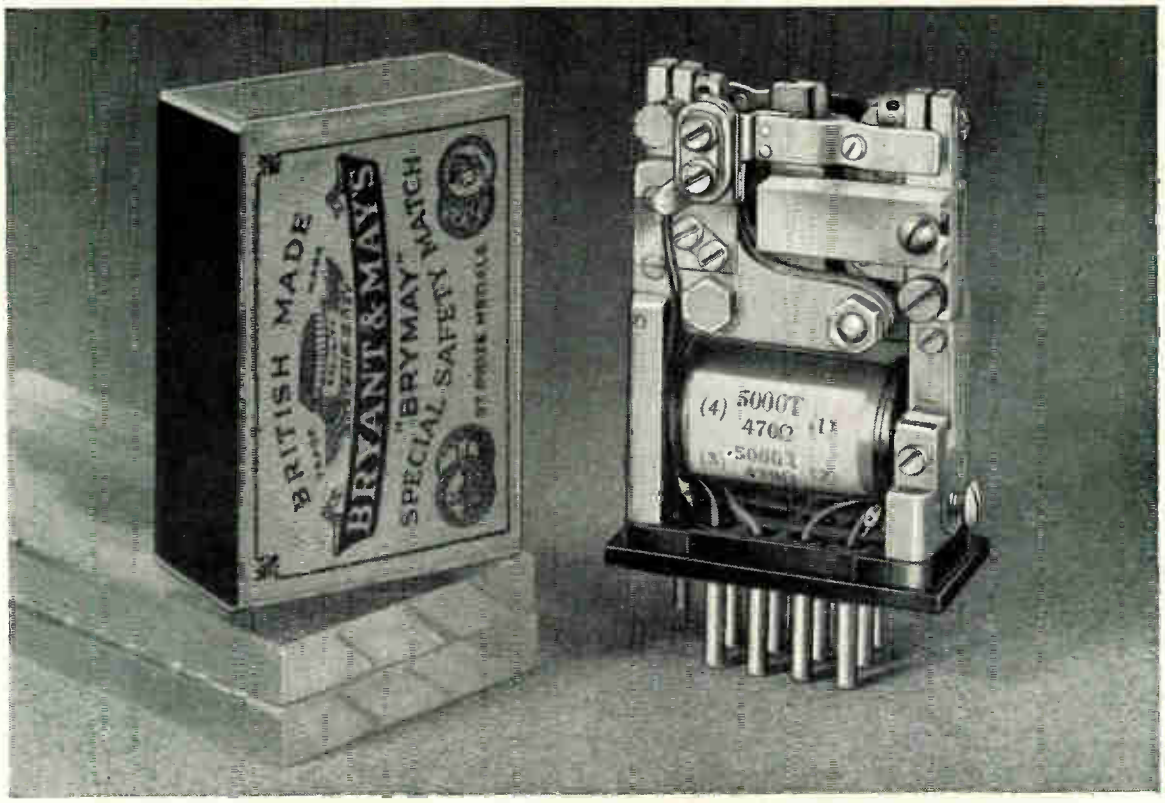

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HIGH OPERATIONAL SPEED • FREEDOM FROM CONTACT REBOUND
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HIGH SENSITIVITY • ACCURACY OF SIGNAL REPETITION
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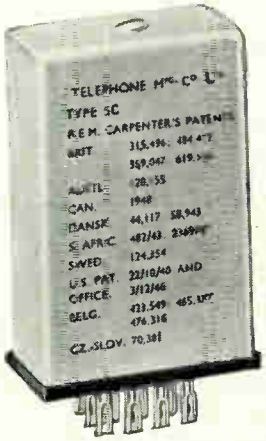

Plug or solder tag base optional.

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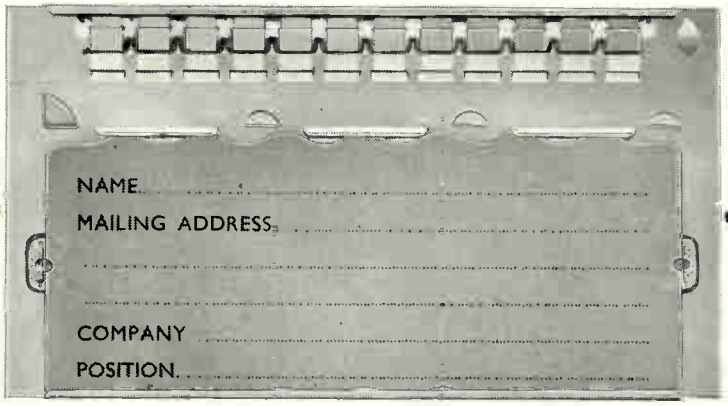

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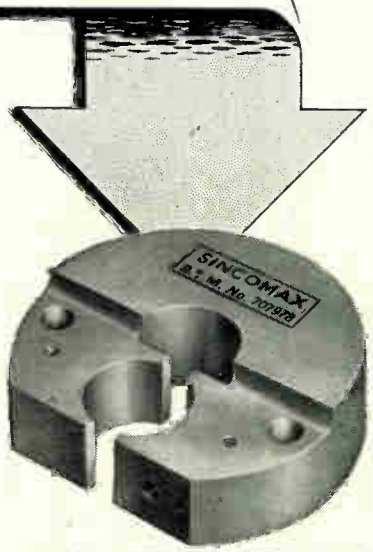

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The only resistor of this class in which the supersensitive carbon film is ceramic encased. Available in ratings of ¼ watt, ½ watt and 1 watt, in values ranging from 10 ohms to 3 megohms, and in tolerances down to ±1%.

ERIE Solid Moulded Carbon Resistors

Available in ratings of ¼ watt, ½ watt and 1 watt, either phenolic or ceramic insulated, in values ranging from 10 ohms to 10 megohms, and in tolerances down to ±5%.

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dependable electronic components

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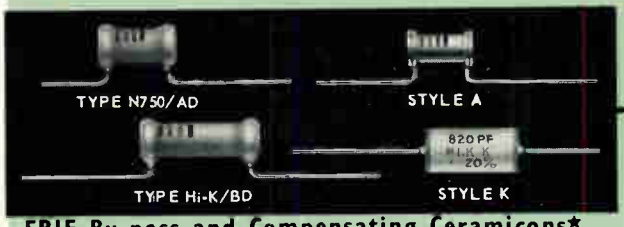

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Specially designed to overcome radiation and critical by-passing problems. Available in values up to 1500 PF.

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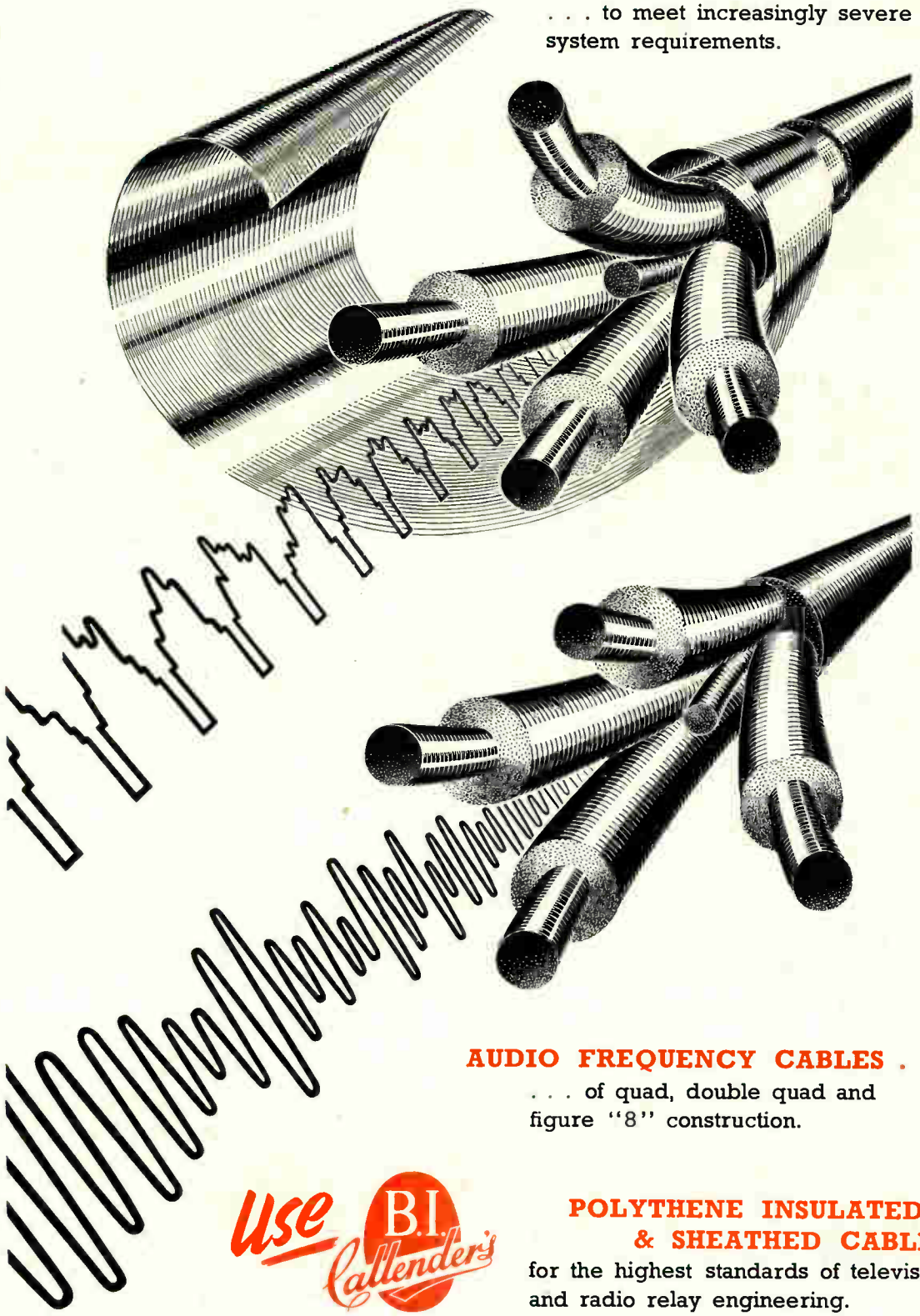

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This new type preserves all the essential stabilizing characteristics of the 'Advance' Standard Constant Voltage Transformer with the additional advantage that it incorporates a circuit to reduce the 3rd harmonic in the output voltage to a very low value (approx. 2% of the fundamental). Used for stabilizing the input voltage to equipment, incorporating rectified power supplies, its performance is similar to that obtained when connected directly to the mains supply, but stabilized to within 1% for an input fluctuation of up to 15%

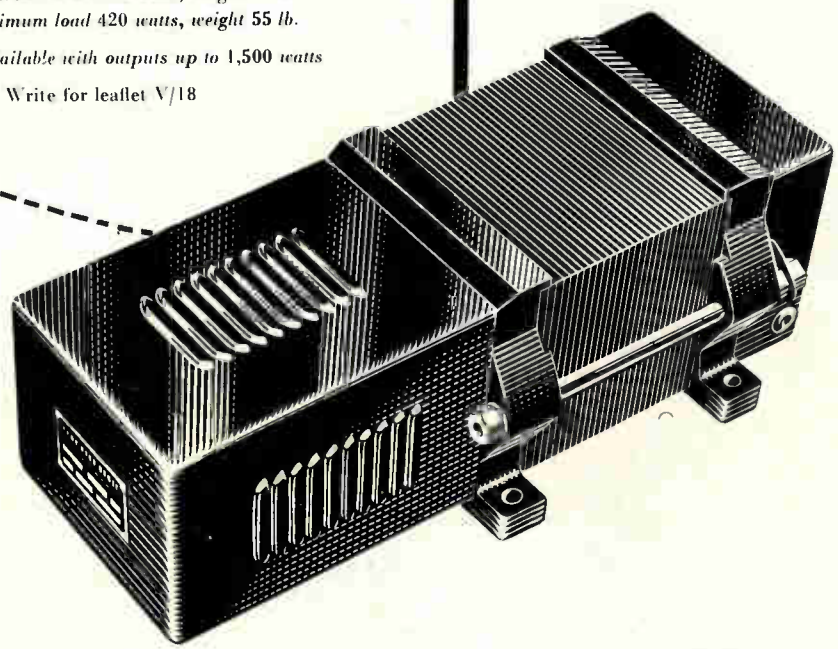
PROVIDES CONSTANT VOLTAGE WITH REDUCED HARMONIC DISTORTION

Input 230 *volts, nominal* (190/260 *volts*) 50 *c/s.*
Output 230 *volts, plus or minus* 1%.

Type CVH 125 — *maximum load* 125 *watts, weight* 20 *lb.*
Type CVH 420 — *maximum load* 420 *watts, weight* 55 *lb.*

Other models available with outputs up to 1,500 *watts*

Write for leaflet V/18



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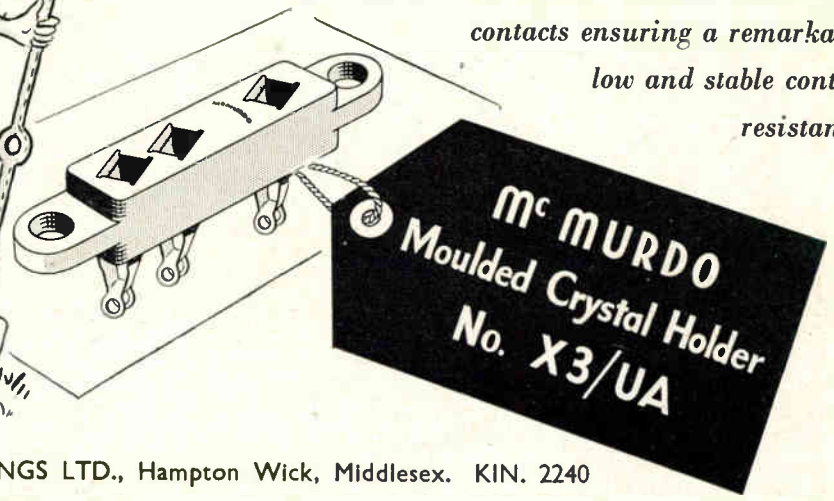

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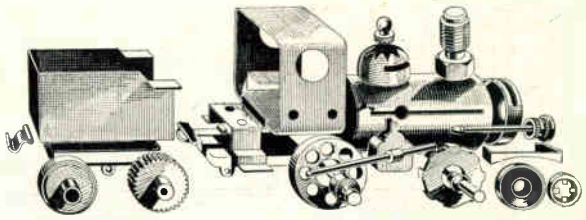

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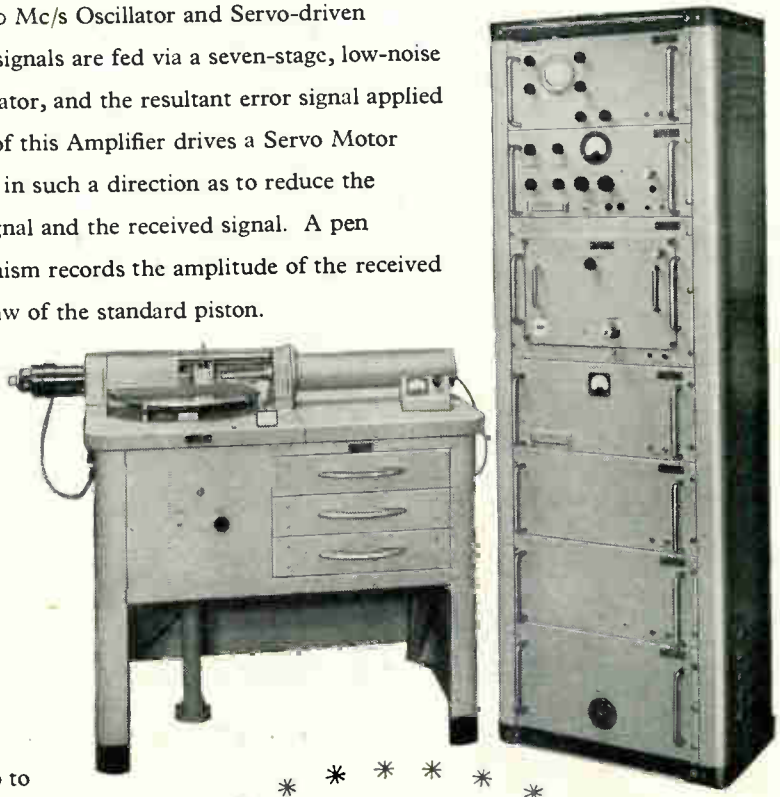
An Equipment for recording

ANTENNA RADIATION PATTERNS

THIS equipment has been developed by EKCO Electronics to automatically record the radiation patterns of any centimetric antenna. The antenna under test is mounted on the roof of a rotatable trailer and illuminated by a fixed transmitter. The amplitude of the received signal is then continuously plotted against the angular traverse of the trailer.

ALL the equipment except the transmitter unit is mounted in the trailer and remote controls for the transmitter are provided. The received C.W. signal is mixed with a modulated Local Oscillator signal and the resultant I.F. output combined with an anti-phase modulated I.F. signal. The reference signal is derived from a 30 Mc/s Oscillator and Servo-driven Piston Attenuator. The combined signals are fed via a seven-stage, low-noise I.F. Amplifier to a balanced Modulator, and the resultant error signal applied to a Servo Amplifier. The output of this Amplifier drives a Servo Motor which moves the Piston Attenuator in such a direction as to reduce the difference between the reference signal and the received signal. A pen attached to the piston drive mechanism records the amplitude of the received signal in terms of the attenuation law of the standard piston.



FACILITIES are available for plotting either on Cartesian or polar co-ordinate graph paper. The amplitude scale in each case is 10dB per inch with a maximum travel of 65dB and the Cartesian co-ordinate paper can be run at rates corresponding to 2 or 5 degrees per inch.

THE Standard Equipment covers the frequency range of 9300 to 9500 m/c. The frequency changer section is a plug-in unit and other frequency ranges can be covered to special order.

ANTENNA PATTERN RECORDER TYPE E59.

EKCO ELECTRONICS LTD. EKCO WORKS, SOUTHEND-ON-SEA, ESSEX.

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SUSPENDED COIL PORTABLE GALVANOMETER UNIT

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A compact, sensitive, yet robustly suspended galvanometer has been developed in our laboratories and, having undergone extensive trials, has proved to be extremely reliable for all purposes. All galvanometers are fitted with shock-absorbing non-sticking stops, thus overloads of up to 100 times full-scale current may be applied without risk of damage to the movement.

It is available as a compact unit for bench use, mounted in a bakelite case measuring only 12 × 8 × 4 cms. and is eminently suitable for mounting in the client's own equipment—a simple bracket mounting is incorporated to facilitate this.

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These Galvanometers are also available as

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MILLIVOLTMETERS
and OHMMETERS

Direct Reading Microammeter. Three ranges (switch selected) 1 μA, 10 μA, and 100μA full scale
Periodic Time: 2 seconds.
Internal resistance: 150 ohms on the 1 μA range.
List No. **T.2010**

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Period Time: 1 second.
Resistance: 200,000 ohms per volt (very low current consumption). Will withstand heavy overload and are suitable for high working speed.
List No. **T.2020**

Direct Reading Ohmmeter. Self-contained single range instruments which may be read with both speed and accuracy.
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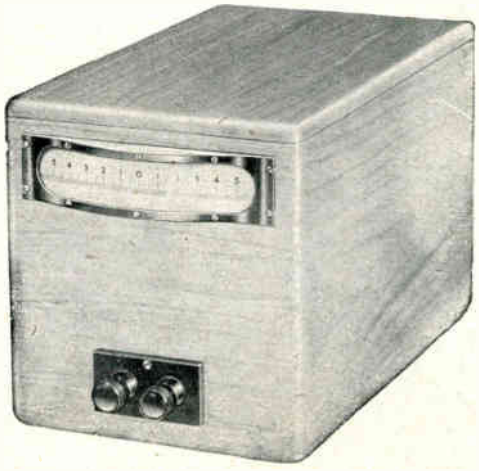

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Volume 31 · Number 3

CONTENTS

MARCH 1954

Editorial: Edwin H. Armstrong **53**

High-Q Coupled Tuned Circuits
by Haim D. Polishuk, M.Sc. **55**

Irregular Transmission Lines
by A. Rosen, Ph.D. **59**

The E-H Surface Wave
by A. E. Karbowiak **71**

Tapped Inductances
by C. R. Cosens, M.A. **74**

Correspondence **75**

New Books **77**

Standard-Frequency Transmissions **78**

Abstracts and References. Nos. 611-918 .. **A.45-A.66**

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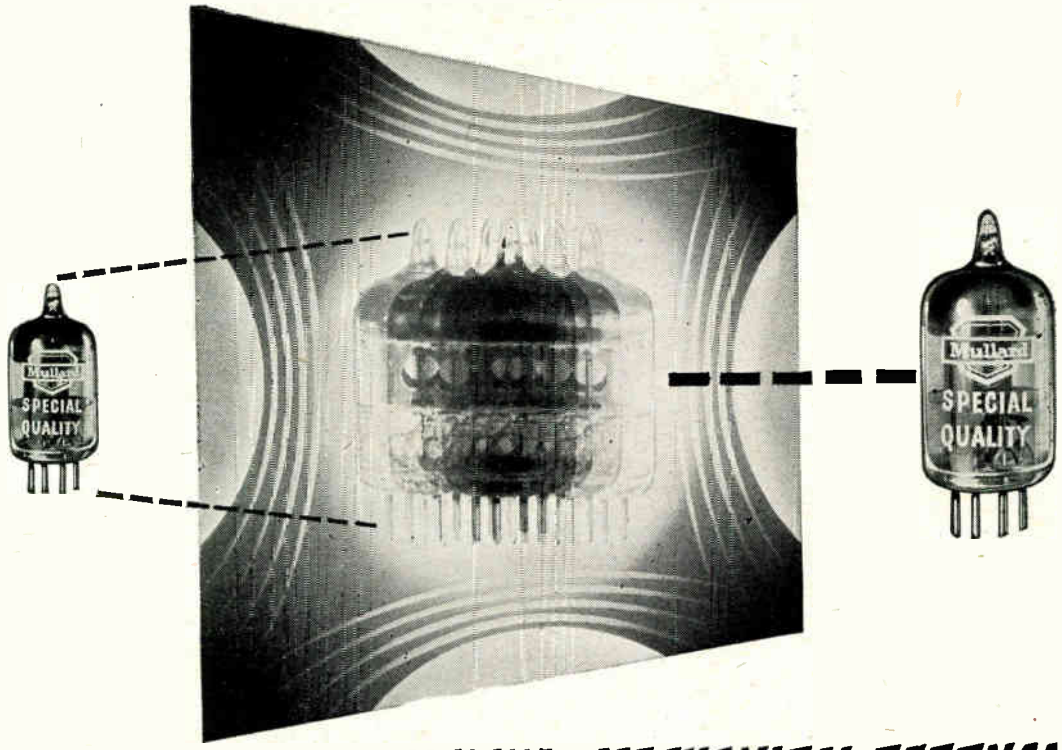

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WIRELESS ENGINEER

Vol. 31 MARCH 1954 No. 3

Edwin H. Armstrong

By his death on 1st February the United States lost one of the outstanding personalities of the wireless world. Edwin Howard Armstrong was born in New York on 18th December 1890. He graduated in Electrical Engineering at Columbia University in 1913 and was awarded an honorary D.Sc. in 1929. He was an assistant in the electrical engineering department for a year after graduation, and then for 21 years collaborated with Michael Pupin in research at the Marcellus Hartley Research Laboratories in Columbia University. From 1934 until his death he was a Professor of Electrical Engineering in the University. During the first world war he spent two years, first as captain and then as major, in the Signal Corps, and in 1919 was made a Chevalier of the Légion d'Honneur.

The name of Armstrong is most closely associated with four inventions, viz. the regenerative circuit, 1912; the superheterodyne system of reception, 1917-18; the superregenerative circuit, 1920; and frequency modulation, 1935. He was a lad of 16 when in 1906 Lee de Forest patented the 3-electrode valve, which became known as the audion, and it was in 1912, while still a student at Columbia, that he was experimenting with an audion when he discovered the presence of h.f. current in the anode circuit, which led to his invention of regeneration and the valve oscillator, and endless patent litigation. In 1914 he published a correct explanation of the action of a triode and disproved some of the currently-accepted ideas; in 1915 he read a paper on regeneration before the Institute of Radio Engineers, and in 1916 another paper on the heterodyne detector. The impact of these papers may be judged from the fact that in the following year the Institute of Radio Engineers awarded him the first Medal of Honour for his work on regeneration and the production of oscillations. Seventeen years later there was a somewhat tragic sequel to this award for, following the adverse decision of the U.S. Supreme Court on the question of priority of invention of these discoveries, he returned the medal to the Institute in 1934. The Board of Directors, however, unanimously declined to accept it and reaffirmed the original award.

Though naturally not entirely unbiased, some light is thrown on this long drawn-out litigation by the autobiography of Lee de Forest, published in 1950. At the same time as Armstrong was experimenting with the audion in New York, Lee de Forest and two assistants were working on somewhat similar lines at Palo Alto in California, and the fight as to who was the prior inventor went on for 20 years.

In the autumn of 1913 de Forest read a paper on "The Audion Amplifier" before the I.R.E. at Columbia University and he says: "My demonstration of the crashing sounds emitted from my loudspeaker when I dropped a handkerchief on the table before the telephone receiver serving as my 'pick-up' aroused great astonishment and applause. On that occasion young Edwin H. Armstrong, wrapped in deepest mystery, had a small carefully-concealed box in an adjoining room into which neither I nor my assistant Logwood was permitted to peek. But when he led two wires to my amplifier input to demonstrate

World Radio History

the squeals and whistles and signals he was receiving from some transmitter down the Bay, we thought we had a pretty fair idea of what the young inventor had concealed in his box of mystery. So we proceeded, meekly and obediently, to amplify whatever signals came over the wires from that room".

That is the first mention of Armstrong in de Forest's autobiography, but early in 1914 de Forest demonstrated his ultra-audion oscillator at the Bureau of Standards in Washington, and he says that Professor Pupin, whom he had long known as a kindly friend, loudly demanded "What right have you to have that here? That thing is not yours. That belongs to Armstrong." He says that he was too flabbergasted to reply, but gazed upon his surprising wrath and "continued the siren sounds." He proceeds, "Then I knew for a certainty what it was that Armstrong had had in his little magic box at Columbia. And that outburst by Professor Pupin was the opening gun of the bitterly contested patent battle to be waged for years in the Patent Office interference proceedings; and thereafter for years more until at long last the U.S. Supreme Court should finally decide the historic contest." Later de Forest says: "On January 15, 1920, I read my paper on the Audion and its evolution before the Franklin Institute at Philadelphia. It was well received, except by one E. H. Armstrong, who sought to show that it was he who had invented the feed-back circuit. 'All de Forest invented was the Audion! We'll concede that', he growled. Whereupon the chairman ordered him to sit down."

The feedback patent, which, after nearly 20 years' litigation, was finally awarded to de Forest, expired in 1941. It had been in turn awarded to Armstrong, then Langmuir, then again to Armstrong, and finally to de Forest. One can appreciate the feelings that prompted Armstrong to return the medal to the Institute.

Another of Armstrong's inventions, with much happier associations, is frequency modulation. This occurred to him as the result of some experiments he and Pupin made with the idea of eliminating static interference; experiments which, he says, were unsuccessful, but which laid the foundations of his system of reducing disturbance by using frequency modulation. In an outline of the history of f.m., which he gave before a section of the I.R.E. in 1946, he said that he started looking for a static eliminator back about 1914, and that he worked a little longer than most people did. He then hit upon the idea of frequency-shift keying and from that went on to frequency modulation. It is pleasing to note that towards the end of his autobiography de Forest says: "Major E. H. Armstrong deserves the greatest credit for the development of his system of frequency-modulation—brought out in spite of the skepticism of the profession, and a reluctant Federal Communications Commission. He has given to radio broadcasting a new arm; for this I salute him."

In 1935 the Radio Club of America founded a medal to be known as the Armstrong Medal. In 1941 Armstrong was awarded the Franklin Medal by the Franklin Institute, and in 1943 the Edison Medal by the American I.E.E.; he was also awarded medals by many other institutions.

In 1947 he received a Medal of Merit and a Presidential Citation for his contributions to military radio communications.

In "Radio: Beam and Broadcast", by A. H. Morse, published in 1925, the patent litigation up to that time is discussed very fully: the author concludes by saying that, "Armstrong's work in radio is such that, had he no patented or patentable inventions—and he has many—he would still rank as one of the foremost exponents of the art". This was before the invention of frequency modulation.

Since 1948 he had been working on what he called the multiplexed transmission of frequency-modulated signals, and as recently as last October he and J. S. Bose, also of Columbia University, read a paper on the subject and gave demonstrations before the Radio Club of America. The multiplex system enables two programmes to be broadcast simultaneously within the standard f.m. band of 200 kc/s. Earlier attempts at multiplexing were not very successful because of cross-modulation between the main and the auxiliary channel and of noise transfer from one to the other, but as the result of five years of work they claimed to have overcome the difficulties, and to be able to obtain results on their second or auxiliary channel superior to those obtained by ordinary amplitude-modulated stations.

One can only regret that so much of his life was overshadowed and embittered by such protracted patent litigation, but during the last 18 years he had the great satisfaction of seeing his frequency modulation becoming more and more highly appreciated, and replacing amplitude modulation on an increasing scale. His name will ever be associated with this outstanding achievement.

G. W. O. H.

World Radio History

HIGH-Q COUPLED TUNED CIRCUITS

By Haim D. Polishuk, M.Sc.

SUMMARY.—By means of a set of expressions developed as functions of a frequency ratio, some aspects of inductively-coupled high-Q resonant circuits are analysed. Considerations of finite, very high-Q circuits lead to simple relations determining impedance characteristics of a fundamental system, resonant frequencies, rate of frequency deviation, input conductance, stored energy and power dissipation ratios.

1. Introduction

THE general subject of inductively-coupled resonant circuits has been treated by many writers and explored with exhaustive rigour. However, present advances in practical analysis of electronic systems, and in particular those related to the u.h.f. domain, suggest an attempt at a somewhat different approach to the investigation of the performance of high-Q coupled tuned circuits. These circuits, apart from constituting the basic frequency-selective communication elements, appear now fundamental in the study of the physical characteristics of an increasing number of u.h.f. applications. For example, electron-tube systems designed for frequency modulation, stabilization and control, where coupled resonant cavities are predominantly employed and for which information of an essentially different nature is sought.

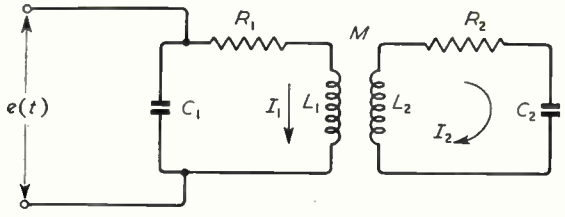

Fig. 1. *Inductively-coupled tuned circuits.*

A fundamental treatment is presented here,* which is also applicable, in many respects, to lower-frequency systems, in which a set of parameters is analytically developed and examined, with the aim of predicting in a general and practical way the steady-state behaviour (excluding mode phenomena) of tightly-coupled high-Q resonant circuits. In expounding the aspects of such circuits a derived group of simple compact expressions is made to determine such information as: effects of tuned-circuit coupling, resultant general resonant frequencies, power dissipation ratio, stored-energy ratio, frequency-deviation rate, resonant conductance characteristics, system effective Q, etc.

MS accepted by the Editor, May 1953

* In a way, an outgrowth of some of the ideas introduced in the works of Sherman, Tellegen, Cuccia and others. See References.

Throughout the following discussion, repetition of elementary or well-known principles has been purposely avoided, except where it is warranted by giving a clearer interpretation of the subject matter.

2. Characteristics of Coupled Impedance

Fig. 1 represents a generalized circuit of an inductively-coupled two-mesh network, excited by a voltage $e(t) = E_0 e^{j\omega_0 t}$, to which a considerable variety of practical systems can be reduced.

Analysis has shown that the series impedance reflected into the primary circuit from the secondary is

$$Z_k = \frac{-(j\omega M)^2}{R_2 + j(\omega L_2 - 1/\omega C_2)} \quad .. \quad .. \quad (1)$$

It should be remembered that this expression of the coupled impedance would not change if, instead of the primary being a tank circuit, a series resonant circuit (C_1 in series with R_1 and L_1) were considered.

The following basic definitions will be used:

ω = $2\pi \times$ frequency

ω_1 = resonant angular frequency of isolated primary circuit $= (L_1C_1)^{-\frac{1}{2}}$

ω_2 = resonant angular frequency of isolated secondary circuit $= (L_2C_2)^{-\frac{1}{2}}$

$Q_1 = \omega_1 L_1/R_1 = 1/\omega_1 C_1 R_1$

$Q_2 = \omega_2 L_2/R_2 = 1/\omega_2 C_2 R_2$

k = effective coefficient of coupling $= M(L_1L_2)^{-\frac{1}{2}}$.

To express Z_k as a function of a frequency ratio, let

$$t = \omega/\omega_2 \quad .. \quad .. \quad .. \quad (2)$$

then, substituting in (1),

$$Z_k = \frac{\omega^2 M^2}{R_2\left(1 + jQ_2\dfrac{t^2 - 1}{t}\right)} \quad .. \quad .. \quad (3)$$

which, after rationalizing and separating, may be put in the form:

$$Z_k = k^2\frac{L_1}{L_2}R_2\left(\frac{t^2}{1 - t^2}\right)^2 + jk^2\omega_2 L_1\frac{t^3}{1 - t^2} \quad (4)$$

where a major simplification was rendered possible by introducing the practical assumption that Q_2 is of very large magnitude, or that

$$1/Q_2^2 \to 0 \quad .. \quad .. \quad .. \quad (5)$$

World Radio History

Considering Z_k as given by (4), it follows that the coupled reactance will remain inductive as long as $t^2 < 1$ or, for all values of $\omega < \omega_2$; whereas, when $t^2 > 1$, or for all values of $\omega > \omega_2$, it will appear capacitive. Moreover, it is noted that beyond the close vicinity of the singularity at $t = 1$, Z_k may be regarded as purely reactive. Fig. 2 reveals the general behaviour of the coupled resistance, R_k, and reactance, X_k, for varying values of t. It is further observed that the coupled reactance will display a maximum at $t = \sqrt{3}$ or, $\omega = \sqrt{3}\omega_2$, and will vary asymptotically between $-\infty$ and the line described by $X_k = -(k^2\omega_2 L_1)\, t$. Concurrently, R_k will vary between $+\infty$ and the line $R_k = k^2 R_2 L_1/L_2 =$ constant.

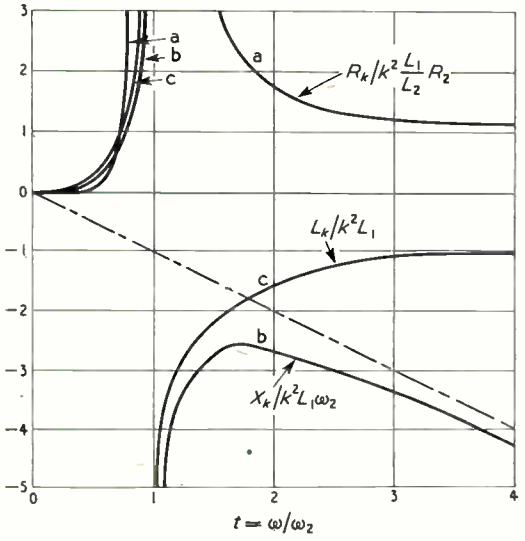

Fig. 2. *General behaviour of coupled resistance, reactance and effective inductance as a function of the ratio* ω/ω_2.

The effective coupled inductance may now be given directly by

$$L_k = \frac{X_k}{\omega} = L_1 k^2 \frac{t^2}{1 - t^2} \quad .. \quad .. \quad (6)$$

a plot of which, as a function of t, is also shown in Fig. 2.

In order to effect a more convenient change of frequency parameters, let us now consider the particular case where $\omega = \omega_0$, the general system resonant angular frequency, and let

$$s = \frac{\omega_0}{\omega_1} \text{ and } p = \frac{\omega_2}{\omega_1} \quad .. \quad .. \quad .. \quad (7)$$

Hence, $t = s/p$ and Z_k, as it is expressed in (4), may be transformed into

$$Z_k = R_1 \cdot \frac{p}{k^2}\frac{Q_1}{Q_2}\left(\frac{s^2 k^2}{s^2 - p^2}\right)^2 - j\omega_0 L_1 \cdot \left(\frac{s^2 k^2}{s^2 - p^2}\right) \quad .. \quad .. \quad .. \quad (8)$$

Putting

$$\beta = \frac{s^2 k^2}{s^2 - p^2} \quad .. \quad .. \quad .. \quad .. \quad (9)$$

and

$$\alpha = \frac{p}{k^2}\frac{Q_1}{Q_2}\beta^2 \quad .. \quad .. \quad .. \quad .. \quad (10)$$

it follows that the inductive branch of the primary circuit could be represented by the equivalent series impedance

$$Z_e = R_1(1 + \alpha) + j\omega_0 L_1(1 - \beta) \quad .. \quad (11)$$

It is thus evident that when $\omega = \omega_0$ the effect of coupling a secondary circuit is to increase the resistive component of the primary impedance by a fractional coefficient α and to reduce the primary inductance by a fractional coefficient β.

3. Resonant Frequencies

When the entire system, considered in the region where $kQ_2 \gg 1$, and reduced effectively to an equivalent circuit composed of impedance $1/j\omega C_1$ in parallel with Z_e, exhibits resonance, the general resonant angular frequency will take the form:

$$\omega_0 = 1/\sqrt{L_1(1 - \beta) \cdot C_1} = \omega_1/\sqrt{1 - \beta} \quad .. \quad .. \quad .. \quad (12)$$

or, $$s^2 = 1/(1 - \beta) \quad .. \quad .. \quad (13)$$

Although conditions justifying relation (12) are to be referred to later in this discussion, it may also be arrived at by starting with a series-resonant primary circuit, developing (by means of Kirchhoff's loop equations) the expression for the driving-point impedance and applying the general resonant condition when voltage is in phase with primary current. From (9) and (13), eliminating s and solving for β,

$$\beta = \frac{(p^2 - 1) \pm \sqrt{(p^2 - 1)^2 + 4k^2p^2}}{2p^2} \quad .. \quad (14)$$

Fig. 3 illustrates the general behaviour of β as a function of p and k, showing variations of both positive and negative roots of β. Considering limiting conditions, it appears that the positive root of β varies asymptotically between $\beta = +1$ and $\beta = k^2$ for all values of k, while the negative root varies between $\beta = 0$ and $\beta = -\infty$, approximating to the hyperbolic relation of $\beta = -p^{-2}$ for small values of p $(1 \gg p^2 > 0)$.

Knowing the value of β, s can be determined readily from (13); furthermore, by substituting (9) in (13), s is expressed directly in terms of p and k, as given by

$$s = \left[\frac{(p^2 + 1) \pm \sqrt{(p^2 - 1)^2 + 4k^2p^2}}{2(1 - k^2)}\right]^{\frac{1}{2}} \quad (15)$$

Evidently, therefore, knowledge of the isolated

World Radio History

frequencies $\omega_2/2\pi$ and $\omega_1/2\pi$ (and k) enables one to determine immediately the value of s and, consequently, the two possible values of $\omega_0/2\pi$ ($= s \times \omega_1/2\pi$), the resultant general (upper and lower) resonant frequencies.

The existence of both positive and negative values of β is supported by the reasoning that at frequencies below $\omega_2/2\pi$ and $\omega_1/2\pi$ the total reactance of the primary circuit is effectively capacitive; hence, the coupled reactance is rendered inductive by β appearing as a negative quantity ($s < 1$). At frequencies above $\omega_2/2\pi$ and $\omega_1/2\pi$, however, the total primary reactance is inductive and upon being balanced by the coupled capacitive reactance ($s > 1$ and positive β), the system will display resonance. It should be observed, moreover, that $1 - \beta$ is always a positive quantity. As a direct result from these conclusions, it follows further that ω_0 can never have a real value within the numerical range $\omega_1 - \omega_2$.

If ω_2 and ω_1 differ only by a very small fractional value such that their ratio may be written as

$$p = 1 \pm 2\Delta \quad .. \quad (16)$$

where, in the power series expansion of p, any but the first-power terms of Δ are negligibly small, the expression for s, as given by (15), reduces to

$$s = \frac{1 \pm \Delta}{\sqrt{1 \pm k}} \quad .. \quad .. \quad (17)$$

Equation (15) also suggests that the upper and lower frequencies become farther apart as k increases in magnitude.

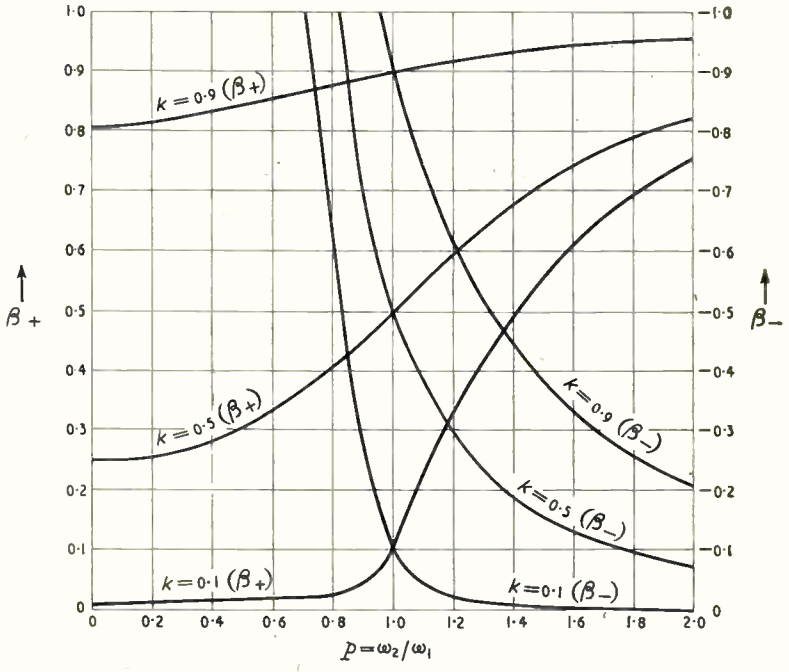

Fig. 3. *Variations of positive and negative values of β as a function of the ratio ω_2/ω_1 for three values of k.*

4. Effects of Resonant Circuit Coupling on Input Conductance

From (11) the total input admittance as seen by the generator will be

$$Y = \frac{1}{R_1(1+\alpha) + j\omega_0 L_1(1-\beta)} + j\omega_0 C_1 \quad (18)$$

and provided $\omega_0 L_1 (1-\beta) \gg R_1 (1+\alpha)$, or:

$$s\,\frac{1-\beta}{1+\alpha} \gg \frac{1}{Q_1} \quad .. \quad .. \quad (19)$$

(18) becomes

$$Y = \frac{R_1(1+\alpha)}{\omega_0^2 L_1^2 (1-\beta)^2} + \frac{1}{j\omega_0 L_1 (1-\beta)} + j\omega_0 C_1$$

$$= \frac{B_1}{Q_1}\left[\frac{1+\alpha}{s^2(1-\beta)^2} + j\frac{Q_1}{s}\left[(s^2-1) - \frac{\beta}{1-\beta}\right]\right]$$

.. .. .. (20)

where B_1 is the magnitude of either primary susceptance at resonance; hence, setting the input susceptance equal to zero yields equation (13).

Since the input conductance at resonance is

$$G_0 = \frac{B_1}{Q_1} \cdot \frac{1+\alpha}{1-\beta} = G_1 \cdot \frac{1+\alpha}{1-\beta} = G_1 \phi \quad .. \quad (21)$$

where $G_1 = C_1 R_1/L_1$ is the conductance of the isolated primary circuit at resonance, it may be stated that inductively coupling a secondary circuit to the primary, effectively changes the ratio R_1 and L_1 by a factor ϕ, where

$$\phi = \frac{1+\alpha}{1-\beta} = (1+\alpha)\, s^2 \quad .. \quad .. \quad (22)$$

Furthermore, in view of provision (19), assuming a high-Q circuit, it follows that the resistive, dynamic impedance of a parallel resonant circuit at resonance, $Z_d = L_1/R_1 C_1$, will change by the factor ϕ^{-1} when a secondary tuned circuit is inductively coupled to it; i.e.,

$$Z_d = \frac{L_1}{R_1 C_1} \cdot \left(\frac{1-\beta}{1+\alpha}\right) \quad .. \quad .. \quad .. \quad (23)$$

World Radio History

In order to arrive at the often instructive condition under which the conductance G_0 will have the same value at both upper and lower values of ω_0, let components involving the two possible values of s be denoted by the numerical subscripts 1 and 2, then,

$$\phi_1 = \phi_2 \quad \text{or} \quad \frac{1+\alpha_1}{1-\beta_1} = \frac{1+\alpha_2}{1-\beta_2}$$

which leads to the following required condition:

$$p^2 + k^2 \frac{Q_2}{Q_1} p - (1 - k^2) = 0 \quad \ldots \quad (24)$$

solving for k would indicate immediately that this condition exists only for values of $p < 1$.

Returning to the definition of ϕ as given by (22), let

L_e = equivalent total inductance = $L_1(1 - \beta)$

R_e = equivalent total resistance = $R_1(1 + \alpha)$, then,

$$\phi = \frac{1+\alpha}{1-\beta} = \frac{R_e/R_1}{L_e/L_1} = \frac{L_1/R_1}{L_e/R_e} = s\frac{Q_1}{Q_0} \quad \ldots \quad (25)$$

where $Q_1 = Q$ of isolated primary
and $Q_0 = Q$ of coupled primary at resonance.

In the particular case where $p = 1$, it follows that

$$\beta = \pm k, \; \alpha = Q_1/Q_2, \; s = (1 \pm k)^{-\frac{1}{2}},$$

$$G_0 = \frac{B_1}{Q_1}\phi = B_1\left(\frac{1}{Q_1} + \frac{1}{Q_2}\right)\frac{1}{1 \pm k}$$

and $$\frac{1}{Q_0} = \frac{\phi}{sQ_1} = \left(\frac{1}{Q_1} + \frac{1}{Q_2}\right)\frac{1}{\sqrt{1 \pm k}}.$$

5. Frequency Deviation Rate

Expression (15) is the solution of the quadratic equation

$$(1 - k^2)\, s^4 - (1 + p^2)\, s^2 + p^2 = 0 \quad (26)$$

which enables one to determine a relationship between small variations of ω_2 and their corresponding effect upon ω_0. It may be shown that

$$\frac{\delta\omega_0}{\delta\omega_2} = \frac{ps}{p^2 + k^2/\beta^2} \quad \ldots \quad (27)$$

or, in terms of a fractional ratio,

$$\frac{\delta\omega_0/\omega_0}{\delta\omega_2/\omega_2} = \frac{p^2}{p^2 + k^2/\beta^2} \quad \ldots \quad (28)$$

6. Power Dissipation Ratio

Let P_1 and P_2 denote, respectively, power dissipated in the primary and secondary circuits, then,

$$\frac{P_1}{P_2} = \frac{R_1}{R_2}\left(\frac{I_1}{I_2}\right)^2 \quad \ldots \quad (29)$$

Applying Kirchhoff's loop equation and allowing for practical values of Q_1 and Q_2 it follows that

$$\frac{P_1}{P_2} = -\frac{p}{s^2 k^2 Q_1 Q_2} - j\frac{1}{Q_1}\frac{2}{s\beta} + \frac{k^2 Q_2}{p\, Q_1 \beta^2}$$

$$\approx \frac{k^2 Q_2}{p\, Q_1 \beta^2} = \frac{1}{\alpha} \quad \ldots \quad (30)$$

Here, if $P_1 = P_2$, α should equal 1; this implies that effective coupled resistance equals primary resistance, which therefore, fulfils the known condition for maximum transfer of power.

7. Stored Energy Ratio

Let W_1 and W_2 represent the energy stored in the primary and secondary circuits, respectively, then,

$$\frac{W_1}{W_2} = \frac{Q_1}{Q_2}\frac{P_1/\omega_1}{P_2/\omega_2} \quad \ldots \quad (31)$$

and, by substituting (30),

$$\frac{W_1}{W_2} = \left(\frac{k}{\beta}\right)^2 \quad \ldots \quad (32)$$

Should $W_1 = W_2$, it follows that p must equal 1, or $\omega_1 = \omega_2$.

Use of (32) may now be made to express the ratio of energy stored in the secondary circuit to the total energy stored in the system; i.e.,

$$\frac{W_2}{W_1 + W_2} = \frac{1}{1 + W_1/W_2} = \frac{1}{1 + (k/\beta)^2} \quad (33)$$

Acknowledgment

The author wishes to express his indebtedness to Major A. Rosenberg, Israel Army, for his constant encouragement and inspiration.

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World Radio History

IRREGULAR TRANSMISSION LINES

Extension of Kennelly's Method of Successive Reflections

By A. Rosen, A.C.G.I., Ph.D., M.I.E.E.

*(Formerly Chief Engineer, Telecommunication Cables, Siemens Brothers & Co., Ltd., Woolwich, London.)**

SUMMARY.—The Kennelly method of successive reflections is developed to provide general expressions for the voltage and current in an irregular line. The irregularities may have any magnitude, and the labour of summing the reflections is reduced by considering the waves in groups. The expressions are given in terms of the reflection coefficients of the local deviations of the characteristic impedance from a defined reference impedance, and they are later simplified for the common practical conditions in which the impedance deviations are small, e.g., the coaxial cable used for wideband telephony and television transmission. The latter formulae are given in series form for the case where the impedance distribution consists of abrupt steps, and as integrals where the distribution is continuous. Finally, the effects of line irregularities on the open- and short-circuit impedances are briefly considered.

LIST OF PRINCIPAL SYMBOLS

The M.K.S. system is used

$j = \sqrt{-1}$
f = frequency in cycles per second
$\omega = 2\pi f$
R = resistance of uniform line per metre
L = inductance of uniform line per metre
C = capacitance of uniform line per metre
G = leakance of uniform line per metre
V = potential difference
I = current
E = e.m.f. of generator
P = propagation coefficient
γ = propagation coefficient per metre
α = attenuation coefficient, nepers per metre
β = phase-change coefficient, radians per metre
Z = characteristic impedance
Z_m = mean characteristic impedance
Z_r = reference impedance
l = length of line
x = distance of point X from sending end O
p = reflection coefficient
m = transmission coefficient
q = transmitted echo coefficient
M = number of irregular sections in line
σ = deviation of local characteristic impedance from Z_r
S = deviation of local characteristic impedance Z_m

Subscripts

AB pertaining to line AB
A or B pertaining to end A or B of line AB
X pertaining to point X
G pertaining to generator
T pertaining to termination
r pertaining to reference impedance

1. Introduction

PROFESSOR A. E. Kennelly presented his method of obtaining the voltages and currents in a transmission line by means of successive reflections in 1907;[1] the paper was limited to the smooth line with various terminal conditions, and since then the method has been extensively taught as an attractive adjunct to more formal treatments. The principle has been extended to irregular lines (e.g., by Aguillon[6] and Schelkunoff[8]) who obtained their results in terms of the reflections between successive portions of the line; such expressions, however, are somewhat cumbersome and difficult to interpret in practical cases. Others (e.g., Didlaukis and Kaden,[3] Merz and Pfleger[4]) have used the device of decomposing the reflection at any one point into two components, each relative to the mean characteristic impedance, but they deal only with small irregularities.

In this paper the reflections are considered relative to a common reference impedance, and the general case is first established in which the irregularities may have any magnitude; this requires the clear definition of such terms as 'reference impedance' and 'principal wave'. Subsequent sections deal with the nominally homogeneous line in which the irregularities are relatively small, and the nature of the resulting approximations is made apparent.

The line with small irregularities has been the subject of much investigation owing to its importance for coaxial cables used for the transmission of wideband telephony and television. The attractiveness of the method of successive reflections lies in the simple mathematical processes used, and in the close analogy to the actual occurrence of the echoes.

2. Voltage and Current Distribution in the Uniform Line

Before dealing with the irregular line, it is desirable to consider briefly the properties of the uniform line. If we have an infinitely long line with uniformly distributed 'primary parameters', viz., resistance, inductance, capacitance and leakance, all per unit length, and apply at the near end a sinusoidal voltage of frequency f and r.m.s. value V_0, the steady-state voltage and current at a point x metres from the sending end are given by

$$\left.\begin{aligned} V_x &= V_0 \exp(-\gamma x) \\ I_x &= \frac{V_0}{Z} \exp(-\gamma x) \end{aligned}\right\} \quad \ldots \quad \ldots \quad (2{\cdot}1)$$

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MS accepted by the Editor, May 1953.

World Radio History

where

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)} \quad (2{\cdot}2)$$

$$Z = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \quad .. \quad .. \quad .. \quad (2.3)$$

The same distribution of voltage and current occurs if the line is of finite length and terminated at its far end by an impedance equal to its characteristic impedance, Z.

3. The General Irregular Line

3.1. *The Reference Line*

In the general case, irregularities in a line may occur as variations from point to point in any of the four primary parameters, R, L, G, C; correspondingly, there will be variations along the line in the secondary parameters, characteristic impedance and propagation coefficient; i.e., both Z and γ are variables whose value may be designated as Z_x and γ_x respectively at a point X, distant x metres from the sending end. It is only the variation of the local characteristic impedance Z_x along the line which gives rise to reflection effects, and to evaluate them the real line is compared with a hypothetical 'reference line' which retains the same distribution of local propagation coefficient γ_x, but is reflectionless in that it has a uniform characteristic impedance Z_r throughout its length. The value of the 'reference impedance' is arbitrary: for a nominally homogeneous line it is chosen to be close to the average characteristic impedance of the irregular line (defined later), and sometimes it is made equal to this value. The reference line is terminated by an impedance Z_r, and the internal impedance of the generator also has this value.

If such a terminated reference line is fed at the near end O by a generator of impedance Z_r and e.m.f. E, the voltage and current at X are

$$\left.\begin{aligned} V_x &= \tfrac{1}{2}E \exp(-P_{ox}) \\ I_x &= \tfrac{1}{2}E \exp(-P_{ox})/Z_r \end{aligned}\right\} \quad .. \quad .. \quad (3.1)$$

where

$$P_{ox} = \int_0^x \gamma_x dx \quad .. \quad .. \quad .. \quad .. \quad (3.2)$$

3.2. *Method of Successive Reflections*

Kennelly[1] showed that the steady-state complex waves of voltage and current existing when a sine-wave e.m.f. is being sent into a line can be resolved into a series of simple waves, and that the series can be formulated by considering the transmission of fictitious waves of voltage and current which are assumed to reach their steady-state values without any build-up period.

When a wave travelling along a line reaches a discontinuity in impedance, a part of the wave is reflected back and a new wave passes on. Another way of regarding this phenomenon is to consider that the passage of the wave across the boundary between two lines of different characteristic impedances leaves it unchanged, but a pair of equal subsidiary waves is thereby generated, one of which travels on with the originating wave, while the other is reflected back in the reverse direction.

The method of successive reflections consists of introducing hypothetical sine-wave voltage and current waves (the principal waves) at the sending end and following their courses along the line; at every discontinuity they each generate a pair of subsidiary waves, and every subsidiary wave when it in turn crosses a discontinuity generates a further pair of subsidiary waves, the process being continued ad infinitum. We trace the courses of all these waves, and obtain the steady-state voltage and current at any point by adding the separate values of all the waves at that point. The values concerned are vectors, the modulus being the r.m.s. value of the wave and the angle the phase relative to a convenient datum, e.g., the generator e.m.f.; for brevity we shall refer to the magnitude, it being understood that both modulus and angle are thereby implied. In general the process of tracing the waves and adding their magnitudes is a tedious one, but by dealing with the waves in groups the labour is considerably reduced.

The principal waves of voltage and current in an irregular line are defined as the steady-state waves which would flow in the reference line terminated by the reference impedance, when fed by a sine-wave generator having the given e.m.f. and of internal impedance equal to the reference impedance.

It is convenient to distinguish the various waves in the following manner:—plus and minus signs indicate respectively progression in the direction from source to termination and vice versa; a letter indicates the point at which the wave is generated and a number the order of the wave generated at that point, e.g., + O1 designates the principal wave, which is the first generated at the origin, and + A2 refers to the second forward-travelling wave generated at A.

3.3. *Reflection and Transmission Coefficients*

If V, I, are the magnitudes of the originating voltage and current waves respectively at the boundary between two semi-infinite lines (Fig. 1), then the magnitudes of the subsidiary voltage and current waves V_s, I_s, are given by

$$\left.\begin{aligned} V_s &= pV \\ I_s &= -pI \end{aligned}\right\} \quad .. \quad .. \quad .. \quad .. \quad (3.3)$$

where

$$p = \frac{Z_2 - Z_1}{Z_2 + Z_1} \quad .. \quad .. \quad .. \quad .. \quad (3.4)$$

World Radio History

Z_2, Z_1, being the respective characteristic impedances of the lines entered and left by the originating wave.

The reflection coefficient of a single discontinuity is defined as the vector ratio of the magnitudes of the reflected and incident waves; similarly, the transmission coefficient is the vector ratio of the magnitudes of the transmitted and incident waves. Referring to Fig. 1, the voltage reflection coefficient is

$$p = \frac{V_s}{V} = \frac{Z_2 - Z_1}{Z_1 + Z_2} \quad .. \quad .. \quad .. \quad (3.5)$$

The current reflection coefficient is

$$p' = \frac{I_s}{I} = \frac{Z_1 - Z_2}{Z_1 + Z_2} = -p \quad .. \quad .. \quad (3.6)$$

The voltage transmission coefficient is

$$m = \frac{V + V_s}{V} = \frac{2Z_2}{Z_1 + Z_2} = 1 + p \quad .. \quad (3.7)$$

The current transmission coefficient is

$$m' = \frac{I + I_s}{I} = \frac{2Z_1}{Z_1 + Z_2} = 1 - p \quad .. \quad (3.8)$$

It will be seen that, for a single discontinuity, the voltage and current reflection coefficients are equal and of opposite sign, whereas the voltage and current transmission coefficients are unequal.

The concept may be extended to cover reflection from and transmission through the whole or any portion of a line. In this case, the reflection coefficient p is defined as the vector ratio of the sum of the reflected waves at the near end of the portion to the principal wave at that point; similarly the transmission coefficient m is the vector ratio of the sum of all the transmitted waves both principal and subsidiary at the far end of the portion to the principal wave at that point. The transmitted echo coefficient q, corresponding to the German term 'Mitfluszfaktor' and the French term 'coefficient de traînage', is the vector ratio of the sum of the subsidiary transmitted waves at the far end of the portion to the principal wave at that point; it is thus equal to $m - 1$.

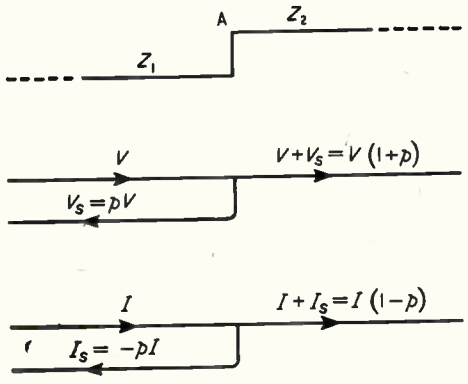


Fig. 1. *Transmitted and reflected waves at a single impedance discontinuity.*

The coefficients will vary according to the impedances of the generator and termination. When the termination and generator have the same impedance, they are said to be matched, and unless the contrary is stated, the coefficients used below refer to matched terminal impedances equal to the reference impedance. Further, the coefficients refer to the voltage waves unless otherwise stated.

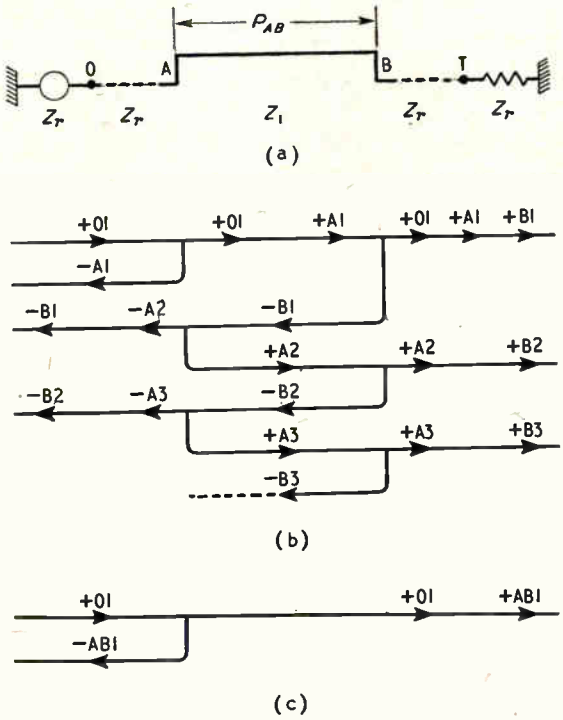


Fig. 2. *Line with one rectangular deviation.*

3.4. *Line with One Rectangular Deviation*

Consider a line of characteristic impedance Z_r, with generator at O and termination at T, both of impedance Z_r [Fig. 2(a)]; inserted in the line between points A and B is a portion of characteristic impedance Z_1 and propagation coefficient P_{AB}, termed a 'rectangular' deviation, from the shape of the diagram. The reflection coefficients relating to the discontinuities at A and B have opposite signs, since, for example, forward-travelling waves at A pass from Z_r to Z_1, whereas at B they pass from Z_1 to Z_r. Forward-travelling waves in portion BT are absorbed at T without reflection, and similarly backward-travelling waves in AO are absorbed at O without reflection.

Considering the voltage along the line [Fig. 2(b)], let the magnitude of the principal wave +01 at A be V; then its magnitude at B is

World Radio History

$V \exp(-P_{AB})$. At A, two subsidiary waves $\pm$ A1 of magnitude Vp_A are generated, where

$$p_A = \frac{Z_1 - Z_r}{Z_1 + Z_r} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.9)$$

Wave $-$ A1 travels back to the source, is absorbed there, and does not generate any further subsidiary waves; $+$ A1 travels forward with the principal wave, making the sum of the two waves at B equal to $V(1 + p_A) \exp(-P_{AB})$.

At B, a pair of subsidiary waves $\pm$ B1 are generated, each of magnitude $-Vp_A(1 + p_A) \exp(-P_{AB})$. The sum of $+$ O1, $+$ A1 and $+$ B1 leaving B towards T is thus

$$V(1 - p^2_A) \exp(-P_{AB}).$$

Let us now trace $-$ B1 travelling from B to A. When it reaches A its magnitude is $-Vp_A(1 + p_A) \exp(-2P_{AB})$; it continues on towards O and in crossing the junction at A, a pair of new waves $\pm$ A2 is generated of magnitude

$$Vp^2_A(1 + p_A) \exp(-2P_{AB}).$$

Of these, $-$A2 travels on to the source and $+$ A2 goes forward to B. The sum of the waves $-$ A1, $-$ B1, $-$A2 returning towards O at this stage is

$$Vp_A\{1 - (1 - p^2_A) \exp(-2P_{AB})\}.$$

Wave $+$ A2 travelling forward has a magnitude $Vp^2_A(1 + p_A) \exp(-3P_{AB})$ at B; it goes on towards T, and in crossing the junction at B it generates $\pm$B2 of magnitude $-Vp^3_A(1 + p_A) \exp(-3P_{AB})$, so that the total going forward to T is now $V[(1 - p^2_A) \exp(-P_{AB}) + (p^2_A - p^4_A) \exp(-3P_{AB})]$. Wave $-$ B2 returns to A, and the process of reflection back and forth between A and B is continued ad infinitum. The magnitudes of the principal and subsidiary waves on the source side of junction A and on the termination side of junction B are given in Table 1.

The total voltage at A is

$$V_A = V[1 + \{1 - \exp(-2P_{AB})\}\{p_A + p^3_A \exp(-2P_{AB}) + p^5_A \exp(-4P_{AB}) + \ldots\}] \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.10)$$

$$= \frac{V(1 + p_A)\{1 - p_A \exp(-2P_{AB})\}}{1 - p^2_A \exp(-2P_{AB})} \quad \ldots \quad (3.11)$$

The total voltage at B is

$$V_B = V \exp(-P_{AB}) \{1 - p^2_A + p^2_A \exp(-2P_{AB}) - p^4_A \exp(-2P_{AB}) + p^4_A \exp(-4P_{AB}) - \ldots\} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3.12)$$

$$= \frac{V(1 - p^2_A) \exp(-P_{AB})}{1 - p^2_A \exp(-2P_{AB})} \quad \ldots \quad \ldots \quad (3.13)$$

The voltage at A, as shown by equation (3.10), consists of the principal wave and a series containing only odd powers of p_A. The voltage at B consists of the principal wave and a series of even powers of p_A.

The current in the line is obtained from the voltage equations by reversing the sign of the odd powers of p_A, the sign of the even powers remaining unchanged. If I is the magnitude of the principal current wave at A, the current at A, I_A, is given by

$$I_A = \frac{I(1 - p_A)\{1 + p_A \exp(-2P_{AB})\}}{1 - p^2_A \exp(-2P_{AB})} \quad (3.14)$$

The current at B is

$$I_B = \frac{I(1 - p^2_A) \exp(-P_{AB})}{1 - p^2_A \exp(-2P_{AB})} \quad \ldots \quad (3.15)$$

The impedance at A looking towards B is from (3.11) and (3.14)

$$Z_{AB} = \frac{Z_r(1 + p_A)\{1 - p_A \exp(-2P_{AB})\}}{(1 - p_A)\{1 + p_A \exp(-2P_{AB})\}} \quad \ldots \quad \ldots \quad \ldots \quad (3.16a)$$

$$= Z_1 \frac{1 - p_A \exp(-2P_{AB})}{1 + p_A \exp(-2P_{AB})} \quad \ldots \quad (3.16b)$$

$$= Z_1 \frac{Z_r \cosh P_{AB} + Z_1 \sinh P_{AB}}{Z_r \sinh P_{AB} + Z_1 \cosh P_{AB}} \quad \ldots \quad (3.17)$$

TABLE 1

Waves in Line with One Rectangular Deviation

Wave	Magnitude in OA at A	Magnitude in BT at B
+ O1	V	$V \exp(-P_{AB})$
− A1	Vp_A	—
+ A1	—	$Vp_A \exp(-P_{AB})$
− B1	—	$-Vp_A(1 + p_A) \exp(-P_{AB})$
− A2	$-Vp_A(1 + p_A) \exp(-2P_{AB})$	—
+ A2	$Vp^2_A(1 + p_A) \exp(-2P_{AB})$	—
+ B2	—	$Vp^2_A(1 + p_A) \exp(-3P_{AB})$
− B2	—	$-Vp^3_A(1 + p_A) \exp(-3P_{AB})$
− A3	$-Vp^3_A(1 + p_A) \exp(-4P_{AB})$	—
+ A3	$Vp^4_A(1 + p_A) \exp(-4P_{AB})$	—
+ B3	—	$Vp^4_A(1 + p_A) \exp(-5P_{AB})$
− B3	—	$-Vp^5_A(1 + p_A) \exp(-5P_{AB})$
etc.	- - -	- - -

World Radio History

The voltage reflection coefficient of portion AB at A is, from equation (3.11)

$$p_{AB} = \frac{p_A\{1 - \exp(-2P_{AB})\}}{1 - p^2{}_A \exp(-2P_{AB})} \quad .. \quad (3.18)$$

and by symmetry, the voltage reflection coefficient at B, p_{BA}, is equal to p_{AB}. From equation (3.14) it is seen that the current reflection coefficient is equal and opposite to the voltage reflection coefficient.

The voltage transmission coefficient is from (3.13)

$$m_{AB} = \frac{1 - p^2{}_A}{1 - p^2{}_A \exp(-2P_{AB})} = 1 - p_A p_{AB} \quad .. \quad .. \quad .. \quad (3.19)$$

Equation (3.15) shows that the current transmission coefficient is equal to the voltage transmission coefficient.

We may form the subordinate waves caused by the passage of the principal wave through the portion AB into two groups. The first group consisting of all waves travelling back from A is designated $-$ AB1; the second, containing all subordinate waves travelling forward from the remote end B is designated $+$ AB1, and we may draw Fig. 2(c) to represent the same series of waves as is shown in Fig. 2(b).

3.5. *Line with Two Rectangular Deviations*

Consider a line OT of impedance Z_T (Fig. 3) in which are inserted a smooth portion AB of impedance Z_1 and propagation coefficient P_{AB} and a second smooth portion CD of impedance Z_2 and propagation coefficient P_{CD}. From Fig. 3 we can construct Table 2, which gives the magnitudes of the various wave-groups at A, B, C and D. The total voltage at A is

$$V_A = V[1 + p_{AB} + p_{CD}m^2{}_{AB} \exp(-2P_{AB} - 2P_{BC}) + p_{BA}p^2{}_{CD}m^2{}_{AB} \exp(-2P_{AB} - 4P_{BC}) + \text{- - -}] \quad .. \quad .. \quad .. \quad (3.20)$$

$$= V\left[1 + p_{AB} + \frac{p_{CD}m^2{}_{AB} \exp(-2P_{AC})}{1 - p_{BA}p_{CD} \exp(-2P_{BC})}\right] \quad .. \quad .. \quad .. \quad (3.21)$$

The total voltage at D is

$$V_D = V\{m_{AB}m_{CD} + p_{BA}p_{CD}m_{AB}m_{CD} \exp(-2P_{BC}) + p^2{}_{BA}p^2{}_{CD}m_{AB}m_{CD} \exp(-4P_{BC}) + \text{- - -}\} \exp(-P_{AD}) \quad .. \quad .. \quad .. \quad (3.22)$$

$$= \frac{Vm_{AB}m_{CD} \exp(-P_{AD})}{1 - p_{BA}p_{CD} \exp(-2P_{BC})} \quad .. \quad .. \quad (3.23)$$

The voltage reflection coefficient for the portion AD is, from (3.21)

TABLE 2

Line with Two Rectangular Deviations

Magnitude of Voltage Waves relative to the Magnitude of the Principal Wave at the Same Point

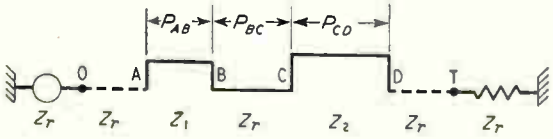
Wave group	Magnitude at A	Magnitude at B	Magnitude at C	Magnitude at D
$+$ O1	1	1	1	1
$-$ AB1	p_{AB}	—	—	—
$+$ AB1	—	$m_{AB} - 1$	$m_{AB} - 1$	$m_{AB} - 1$
$+$ CD1	—	—	—	$m_{AB}(m_{CD} - 1)$
$-$ CD1	$p_{CD}m_{AB} \exp(-2P_{AB} - 2P_{BC})$	$p_{CD}m_{AB} \exp(-2P_{BC})$	$p_{CD}m_{AB}$	—
$-$ AB2	$p_{CD}m_{AB}(m_{AB} - 1) \exp(-2P_{AB} - 2P_{BC})$	—	—	—
$+$ AB2	—	$p_{BA}p_{CD}m_{AB} \exp(-2P_{BC})$	$p_{BA}p_{CD}m_{AB} \exp(-2P_{BC})$	$p_{BA}p_{CD}m_{AB} \exp(-2P_{BC})$
$+$ CD2	—	—	—	$p_{BA}p_{CD}m_{AB}(m_{CD} - 1) \exp(-2P_{BC})$
$-$ CD2	$p_{BA}p^2{}_{CD}m_{AB} \exp(-2P_{AB} - 4P_{BC})$	$p_{BA}p^2{}_{CD}m_{AB} \exp(-4P_{BC})$	$p_{BA}p^2{}_{CD}m_{AB} \exp(-2P_{BC})$	—
$-$ AB3	$p_{BA}p^2{}_{CD}m_{AB}(m_{AB} - 1) \exp(-2P_{AB} - 4P_{BC})$	—	—	—
$+$ AB3	—	$p^2{}_{BA}p^2{}_{CD}m_{AB} \exp(-4P_{BC})$	$p^2{}_{BA}p^2{}_{CD}m_{AB} \exp(-4P_{BC})$	$p^2{}_{BA}p^2{}_{CD}m_{AB} \exp(-4P_{BC})$
$+$ CD3	—	—	—	$p^2{}_{BA}p^2{}_{CD}m_{AB}(m_{CD} - 1) \exp(-4P_{BC})$
etc.	- - -	- - -	- - -	- - -

World Radio History

$$p_{AD} = p_{AB} + \frac{p_{CD} m^2_{AB} \exp(-2P_{AC})}{1 - p_{BA} p_{CD} \exp(-2P_{BC})} \quad (3.24)$$

The voltage transmission coefficient for AD is, from (3.23)

$$m_{AD} = \frac{m_{AB} m_{CD}}{1 - p_{BA} p_{CD} \exp(-2P_{BC})} \quad .. \quad (3.25)$$



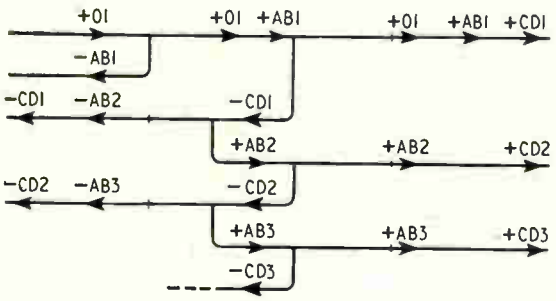


Fig. 3. *Line with two rectangular deviations.*

If generator and termination are interchanged in Fig. 3, we obtain the reflection and transmission coefficients for transmission through the line from D to A. From (3.24) and (3.25) we obtain from considerations of symmetry

$$p_{DA} = p_{DC} + \frac{p_{BA} m^2_{CD} \exp(-2P_{BD})}{1 - p_{BA} p_{CD} \exp(-2P_{BC})} \quad (3.26)$$

$$m_{DA} = \frac{m_{AB} m_{CD}}{1 - p_{BA} p_{CD} \exp(-2P_{BC})} = m_{AD} \quad (3.27)$$

If the two portions are adjacent, $P_{BC} = 0$. Then for two adjacent rectangular deviations,

$$p_{AC} = p_{AB} + \frac{p_{BC} m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA} p_{BC}} \quad .. \quad (3.28)$$

$$p_{CA} = p_{CB} + \frac{p_{BA} m^2_{BC} \exp(-2P_{BC})}{1 - p_{BA} p_{BC}} \quad .. \quad (3.29)$$

$$m_{AC} = m_{CA} = \frac{m_{AB} m_{BC}}{1 - p_{BA} p_{BC}} \quad .. \quad .. \quad (3.30)$$

By following a similar procedure for the current waves, we obtain equations corresponding to (3.24), (3.25), (3.26) and (3.27); we see that for two rectangular deviations the voltage and current reflection coefficients at the same end are equal and opposite to each other, while the voltage and current transmission coefficients are equal to each other and are the same for either direction of transmission.

3.6. *Line with M Adjacent Rectangular Deviations*

If the line contains three rectangular deviations adjacent to each other, AB, BC, CD, we treat it as two portions AC, CD, and by following the process used for two rectangular deviations we arrive at the equations

$$\begin{aligned} p_{AD} &= p_{AC} + \frac{m^2_{AC} p_{CD} \exp(-2P_{AC})}{1 - p_{CA} p_{CD}} \\ &= p_{AB} + \frac{m^2_{AB} p_{BC} \exp(-2P_{AB})}{1 - p_{BA} p_{BC}} \\ &\quad + \frac{m^2_{AC} p_{CD} \exp(-2P_{AC})}{1 - p_{CA} p_{CD}} \quad .. \quad (3.31) \end{aligned}$$

$$m_{AD} = \frac{m_{AC} m_{CD}}{1 - p_{CA} p_{CD}} = \frac{m_{AB} m_{BC} m_{CD}}{(1 - p_{BA} p_{BC})(1 - p_{CA} p_{CD})} \quad .. \quad .. \quad .. \quad (3.32)$$

When the line contains M adjacent rectangular deviations AB, BC . . . MN, we obtain by continuing the process

$$\begin{aligned} p_{AN} &= p_{AB} + \frac{m^2_{AB} p_{BC} \exp(-2P_{AB})}{1 - p_{BA} p_{BC}} \\ &\quad + \frac{m^2_{AC} p_{CD} \exp(-2P_{AC})}{1 - p_{CA} p_{CD}} \\ &\quad + \cdots\cdots + \frac{m^2_{AM} p_{MN} \exp(-2P_{AM})}{1 - p_{MA} p_{MN}} \\ &\quad .. \quad .. \quad .. \quad (3.33) \end{aligned}$$

$$m_{AN} = m_{NA} = \frac{m_{AB} m_{BC} \cdots\cdots m_{MN}}{(1 - p_{BA} p_{BN})(1 - p_{CB} p_{CN}) \cdots\cdots (1 - p_{LM} p_{MN})} \quad .. \quad (3.34)$$

$$= \frac{m_{AB} m_{BC} \cdots\cdots m_{MN}}{(1 - p_{BA} p_{BC})(1 - p_{CA} p_{CD}) \cdots\cdots (1 - p_{MA} p_{MN})} \quad .. \quad (3.35)$$

3.7. *Line with Deviations of any Form*

A deviation AB of any form may be regarded as one composed of a large number of adjacent rectangular deviations of very short length. The forward-travelling subsidiary waves may be grouped together to form a single wave-group + AB1, and the backward-travelling subsidiaries may be grouped to form a second wave-group − AB1, the whole process being represented by Fig. 2(c). Thus Sections (3.5) and (3.6), with the contained equations (3.20) to (3.35) inclusive and Table 2, apply mutatis mutandis to lines with deviations of any form.

The following relations pertain to a line AB containing deviations of any form, with matched terminal conditions:—

(*a*) The voltage and current reflection coefficients at the same end are equal and opposite in sign to each other.

(*b*) It follows from (*a*) that if p_{AB} is the voltage reflection coefficient, Z_{AB} the impedance looking

World Radio History

into the line at A and Z_r the impedance of the generator and termination

$$V_A = V(1 + p_{AB})$$
$$I_A = I(1 - p_{AB})$$

whence $$Z_{AB} = \frac{Z_r(1 + p_{AB})}{1 - p_{AB}} \quad .. \quad .. \quad (3.36)$$

$$p_{AB} = \frac{Z_{AB} - Z_r}{Z_{AB} + Z_r} \quad .. \quad .. \quad .. \quad (3.37)$$

(*c*) The reflection coefficients at end B in general bear no relation to the reflection coefficients at end A.

(*d*) The voltage and current transmission coefficients are equal to each other.

(*e*) The voltage and current transmission coefficients are the same for either direction of transmission; this may be deduced directly from the Reciprocity Theorem.

3.8. *Irregular Line with General Terminal Conditions*

If an irregular line is terminated with an impedance Z_T other than the reference impedance Z_r, the voltage reflection coefficient p_{ABT} may be obtained from equation (3.28) in its general application by substituting p_T for p_{BC}, where

$$p_T = \frac{Z_T - Z_r}{Z_T + Z_r} \quad .. \quad .. \quad .. \quad (3.38)$$

Thus $$p_{ABT} = p_{AB} + \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA}p_T} \quad (3.39)$$

Similarly, for the opposite direction of transmission

$$p_{BAT} = p_{BA} + \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{AB}p_T} \quad (3.40)$$

The voltage transmission coefficient m_{ABT} is obtained from equation (3.30) by substituting $(1 + p_T)$ for m_{BC}. Thus

$$m_{ABT} = \frac{m_{AB}(1 + p_T)}{1 - p_{BA}p_T} \quad .. \quad .. \quad (3.41)$$

$$m_{BAT} = \frac{m_{AB}(1 + p_T)}{1 - p_{AB}p_T} \quad .. \quad .. \quad (3.42)$$

The current reflection coefficient in terms of the voltage coefficients for the component parts is

$$p'_{ABT} = -p_{AB} - \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA}p_T} \quad .. \quad .. \quad .. \quad .. \quad (3.43)$$

Similarly the current transmission coefficient is

$$m'_{ABT} = \frac{m_{AB}(1 - p_T)}{1 - p_{BA}p_T} \quad .. \quad .. \quad (3.44)$$

The current reflection coefficient is equal and opposite to the voltage reflection coefficient, so that the relationships between impedance and reflection coefficients, equations (3.36) and (3.37), hold good. The voltage and current transmission coefficients, however, are no longer equal to each other, and furthermore, they differ for the two directions of transmission.

The voltage at the sending end is

$$V_A = V(1 + p_{ABT}) = V\left\{1 + p_{AB} + \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA}p_T}\right\} \quad .. \quad .. \quad .. \quad .. \quad (3.45)$$

where V is the magnitude of the principal voltage wave at the sending end. The current at the sending end is

$$I_A = I\left\{1 - p_{AB} - \frac{p_T m^2_{AB} \exp(-2P_{AB})}{1 - p_{BA}p_T}\right\} \quad .. \quad .. \quad .. \quad .. \quad (3.46)$$

where I is the magnitude of the principal current wave at the sending end. Thus the sending-end impedance is

$$Z_{ABT} = \frac{Z_r(1 + p_{ABT})}{1 - p_{ABT}} = Z_r\left[\frac{(1 + p_{AB})(1 - p_{BA}p_T) + p_T m^2_{AB} \exp(-2P_{AB})}{(1 - p_{AB})(1 - p_{BA}p_T) - p_T m^2_{AB} \exp(-2P_{AB})}\right] \quad .. \quad (3.47)$$

If the generator impedance is changed and its e.m.f. remains unaltered at E, the principal voltage wave, by definition, is unaffected. If the new value of the generator impedance is Z_G, the voltage at the sending end of the line terminated by Z_T becomes $EZ_{ABT}/(Z_G + Z_{ABT})$. The corresponding value of the principal wave is $\frac{1}{2}E$, the new reflected wave is $\frac{1}{2}E(Z_{ABT} - Z_G)/(Z_{ABT} + Z_G)$, and thus the new reflection coefficient p_{GABT} is

$$p_{GABT} = \frac{Z_{ABT} - Z_G}{Z_{ABT} + Z_G} \quad .. \quad .. \quad .. \quad (3.48)$$

which is in agreement with the accepted definition of reflection coefficient. From equations (3.47) and (3.48) we have

$$p_{GABT} = \frac{(p_{AB} + p_G)(1 - p_{BA}p_T) + p_T m^2_{AB} \exp(-2P_{AB})}{(1 + p_{AB}p_G)(1 - p_{BA}p_T) + p_G p_T m^2_{AB} \exp(-2P_{AB})} \quad .. \quad (3.49)$$

where $$p_G = (Z_r - Z_G)/(Z_r + Z_G) \quad .. \quad (3.50)$$

The effect of changing the generator impedance from Z_r to Z_G is to alter the received voltage in the ratio $(Z_{ABT} + Z_r)/(Z_{ABT} + Z_G)$. Since the principal wave is unaltered, the new transmission coefficient m_{GABT} becomes

World Radio History

$$m_{GABT} = \frac{m_{ABT}(Z_{ABT} + Z_T)}{Z_{ABT} + Z_G} = \frac{m_{AB}(1 + p_G)(1 + p_T)}{(1 + p_{AB}p_G)(1 - p_{BA}p_T) + p_G p_T m^2_{AB} \exp(-2P_{AB})} \quad .. \quad (3.51)$$

If $Z_T = Z_G$ (i.e., the terminations are matched at the new value Z_G instead of Z_T) $p_G = -p_T$, and

$$p_{GABG} = \frac{(p_{AB} + p_G)(1 + p_{BA}p_G) - p_G m^2_{AB} \exp(-2P_{AB})}{(1 + p_{AB}p_G)(1 + p_{BA}p_G) - p^2_G m^2_{AB} \exp(-2P_{AB})} \quad .. \quad (3.52)$$

$$m_{GABG} = \frac{m_{AB}(1 - p^2_G)}{(1 + p_{AB}p_G)(1 + p_{BA}p_G) - p^2_G m^2_{AB} \exp(-2P_{AB})} \quad .. \quad (3.53)$$

In the above, the coefficients p_{AB}, p_{BA}, m_{AB} relate to the reference impedance Z_T. Changing the reference impedance will not alter either the actual line voltages or the principal voltage wave, and hence p_{GABG} and m_{GABG} are unaffected by a change in the reference impedance, e.g., from Z_T to Z_G. Thus equations (3.52) and (3.53) give the change in the reflection and transmission coefficients respectively when the reference impedance is changed from Z_T to Z_G.

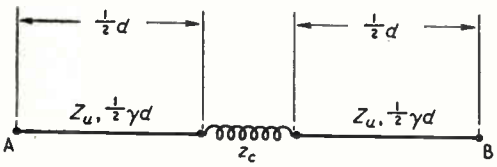


Fig. 4. *Section of loaded cable.*

3.9. *Localized Irregularities*

A localized irregularity is one in which a relatively large impedance deviation has such a small propagation coefficient that it is effectively concentrated at a single point; e.g., a series inductor or a shunt capacitor. The reflection and transmission coefficients can be obtained directly from the definitions and the elementary circuit diagrams, but it is instructive to see how they follow from the general case. The propagation coefficient being very small, the reflection coefficient is from equation (3.18)

$$p_{AB} = \frac{2P_{AB}p_A}{1 - p^2_A(1 - 2P_{AB})} = \frac{2P_{AB}(Z^2_1 - Z^2_T)}{4Z_1Z_T + 2P_{AB}(Z_1 - Z_T)^2} \quad .. \quad (3.54)$$

If the deviation is due to a relatively large series impedance z_c associated with a small shunt admittance y_c (such as a loading coil), $Z^2_1 = z_c/y_c$ is large compared with Z^2_T, and hence

$$p_{AB} = \frac{P_{AB}Z_1}{2Z_T + P_{AB}Z_1}$$

Since $p_{AB} = \sqrt{z_c y_c}$, we have

$$p_{AB} = \frac{z_c}{2Z_T + z_c} \quad .. \quad .. \quad .. \quad (3.55)$$

From equation (3.19), since $p_A \approx 1$,

$$m_{AB} = 1 - \frac{z_c}{2Z_T + z_c} = \frac{2Z_T}{2Z_T + z_c} \quad .. \quad (3.56)$$

On the other hand if the shunt admittance is relatively large and the series impedance small, Z^2_1 can be neglected relative to Z^2_T, and $p_A \approx -1$. Whence

$$p_{AB} = \frac{-P_{AB}Z_T}{2Z_1 + P_{AB}Z_T} = \frac{-y_cZ_T}{2 + y_cZ_T} \quad .. \quad (3.57)$$

$$m_{AB} = 1 - \frac{y_cZ_T}{2 + y_cZ_T} = \frac{2}{2 + y_cZ_T} \quad .. \quad (3.58)$$

It is interesting to use these relations to obtain Campbell's formula for the loaded cable. Referring to Fig. 4, AB represents a loading coil of impedance z_c inserted between two portions of cable, each of length $\frac{1}{2}d$, of characteristic impedance Z_u and propagation coefficient γ per unit length. If we choose the reference impedance to be Z_u, we have

$$p_{AB} = \frac{z_c \exp(-\gamma d)}{z_c + 2Z_u}; \quad m_{AB} = \frac{2Z_u}{z_c + 2Z_u} \quad .. \quad .. \quad .. \quad (3.59)$$

The impedance with end B open-circuited is obtained from equation (3.47), for which $p_T = +1$; whence

$$Z_{op} = Z_u\left[\frac{1 - p^2_{AB} + m^2_{AB}\exp(-2\gamma d)}{(1 - p_{AB})^2 - m^2_{AB}\exp(-2\gamma d)}\right].$$

Similarly with end B short-circuited, $p_T = -1$, and

$$Z_{sh} = Z_u\left[\frac{(1 + p_{AB})^2 - m^2_{AB}\exp(-2\gamma d)}{1 - p^2_{AB} + m^2_{AB}\exp(-2\gamma d)}\right]$$

If P' is the propagation coefficient per unit length of the loaded cable, then

$$\tanh^2 P'd = \frac{Z_{sh}}{Z_{op}} = 1 - \frac{4m^2_{AB}\exp(-2\gamma d)}{\{1 - p^2_{AB} + m^2_{AB}\exp(-2\gamma d)\}^2}$$

Whence

$$\cosh P'd = \frac{1 - p^2_{AB} + m^2_{AB}\exp(-2\gamma d)}{2m_{AB}\exp(-\gamma d)}$$

and substituting from (3.59) we have

$$\cosh P'd = \cosh \gamma d + \frac{z_c}{2Z_u}\sinh \gamma d \quad .. \quad (3.60)$$

which is Campbell's well-known formula.

World Radio History

4. Line with Small Irregularities

4.1. Simplification when Impedance Deviations are Small

If the impedance deviations are small relative to the reference impedance, the reflection coefficients p_A, p_B, etc., are small compared with unity. The coefficients for one deviating smooth portion from (3.18) and (3.19) simplify to

$$p_{AB} = p_A\{1 - \exp(-2P_{AB})\} \quad .. \quad (4.1)$$

$$m_{AB} = 1 - p^2_A\{1 - \exp(-2P_{AB})\} \quad .. \quad (4.2)$$

Considering M adjacent smooth portions, we find by substituting (4.1) and 4.2) in equation (3.33) that terms of the type $m^2_{AB}p_{BC}/(1 - p_{BA}p_{BC})$ reduce to p_{BC}. Thus we have

$$p_{AN} = p_{AB} + p_{BC}\exp(-2P_{AB}) + p_{CD}\exp(-2P_{AC}) + - - - - - + p_{MN}\exp(-2P_{AM}) \quad .. \quad .. \quad (4.3)$$

Equation (4.3) shows that the reflected wave from each deviating portion is the same as if the line between it and the source were smooth; further, only single reflections and consequently first powers of reflection coefficients are of importance. The corresponding wave-diagram is shown in Fig. 5.

The transmission coefficient for two deviating portions, from (3.25) reduces to

$$\begin{aligned} m_{AD} &= m_{AB}m_{CD}\{1 + p_{BA}p_{CD}\exp(-2P_{BC})\} \\ &= 1 - p^2_A\{1 - \exp(-2P_{AB})\} \\ &\quad - p^2_C\{1 - \exp(-2P_{CD})\} \\ &\quad + p_Ap_C\exp(-2P_{BC})\{1 - \exp(-2P_{AB})\} \\ &\quad \{1 - \exp(-2P_{CD})\} \quad .. \quad .. \quad .. \quad (4.4) \end{aligned}$$

Only second powers of reflection coefficients and double reflections are concerned; the corresponding wave-diagram is shown in Fig. 6.

For M adjacent smooth portions, the transmission coefficient, from (3.34) becomes

$$m_{AN} = m_{AB}m_{BC}m_{CD} \ldots\ldots m_{MN}(1 + p_{BA}p_{BC} + p_{CA}p_{CD} + - - - - + p_{MA}p_{MN}) \quad (4.5)$$

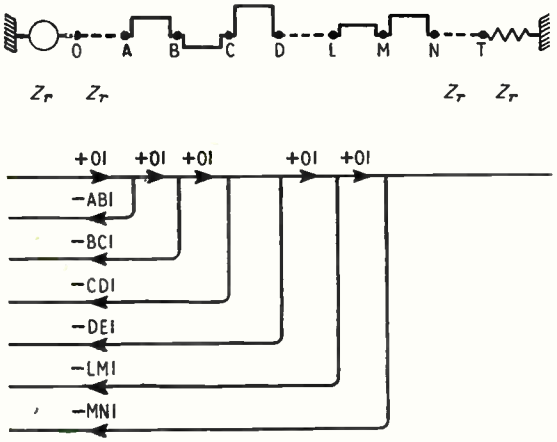


Fig. 5. *Single reflections in line with small rectangular deviations.*

$$\begin{aligned} &= 1 - p^2_A\{1 - \exp(-2P_{AB})\} \\ &\quad - p^2_B\{1 - \exp(-2P_{BC})\} - \\ &\quad - - - - - p^2_M\{1 - \exp(-2P_{MN})\} \\ &\quad + p_{BC}p_{BA} + p_{CD}\{p_{CB} + p_{BA}\exp(-2P_{BC})\} \\ &\quad + - - - - + p_{MN}\{p_{ML} + p_{LK}\exp(-2P_{LM}) \\ &\quad + - - - - + p_{BA}\exp(-2P_{BM})\} \end{aligned}$$

$$= 1 - \sum_{F=A}^{M} p^2_F\{1 - \exp(-2P_{FG})\} + \sum_{F=B}^{M} p_{FG}\left\{\sum_{D=B}^{F} p_{DG}\exp(-2P_{DF})\right\}$$

$$= 1 - \sum_{F=A}^{M} p^2_F\{1 - \exp(-2P_{FG})\} + \sum_{F=B}^{M} p_F\{1 - \exp(-2P_{FG})\} \left[\sum_{D=B}^{F} p_C\{1 - \exp(-2P_{CD})\}\exp(-2P_{DF})\right] \quad (4.6)$$

By similar reasoning to the above, we can see that (4.3) and (4.5) apply also to an arrangement of M adjacent irregular portions.

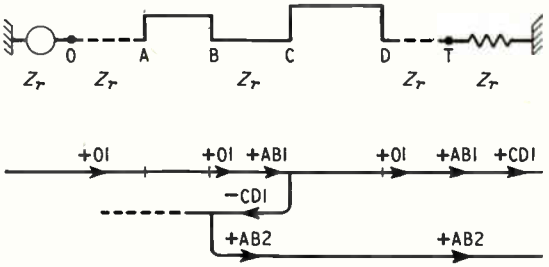


Fig. 6. *Double reflection in line with two small rectangular deviations.*

4.2. Irregular Line with General Terminal Conditions

Consider the irregular line AB treated in Section (3.8) in which the generator impedance is changed from Z_T to Z_G and the terminating impedance from Z_T to Z_T; when the line irregularities are small the reflection coefficient p_{GABT} in (3.49) becomes

$$p_{GABT} = \frac{(p_{AB} + p_G)(1 - p_{BA}p_T) + p_T\exp(-2P_{AB})}{1 + p_{AB}p_G - p_{BA}p_T + p_Gp_T\exp(-2P_{AB})}$$

If $p_Gp_T\exp(-2P_{AB})$ is small compared with 1, which is often the case,

$$p_{GABT} = p_{AB} + p_G + p_T\exp(-2P_{AB}) - p_{AB}p^2_G \quad .. \quad .. \quad .. \quad .. \quad (4.7)$$

From (3.51) we obtain for the transmission coefficient

$$m_{GABT} = m_{AB}(1 + p_G)(1 + p_T)\{1 - p_{AB}p_G + p_{BA}p_T - p_Gp_T\exp(-2P_{AB})\} \quad .. \quad .. \quad .. \quad (4.8)$$

World Radio History

If q_{AB} denotes the transmitted echo coefficient when generator and termination are equal to Z_r, and q_{GABT} the value when these impedances are respectively Z_G and Z_T, then

$$q_{GABT} = (1 + p_G)(1 + p_T)$$
$$\{q_{AB} - p_{AB}p_G + p_{BA}p_T - p_Gp_T \exp(-2P_{AB})\}$$
$$.. \quad .. \quad .. \quad (4.9)$$

In (4.7) we recognise in p_{AB} the term representing the single reflections within the line; in p_G the first-order reflected wave due to the mis-match between the generator and line; in $p_T \exp(-2P_{AB})$ the reflection from the mis-match between termination and line, modified by the propagation coefficient due to a double traverse of the line; and in $p^2_G p_{AB}$ the third-order reflection between generator and line which may be appreciable if the mis-match is large. In (4.9) we distinguish q_{AB} due to double reflections within the line; $p_{AB}p_G$ representing single reflections in the line reflected again at the generator; $p_{BA}p_T$ representing reflection from the termination reflected again in the line; and $p_Gp_T \exp(-2P_{AB})$ representing double reflection between termination and generator.

If $Z_G = Z_T$ and the mismatch between line and terminal impedances is small, then

$$p_{GABG} = p_{AB} + p_G\{1 - \exp(-2P_{AB})\} \quad (4.10)$$
$$m_{GABG} = m_{AB} - p^2_G - p_G(p_{AB} + p_{BA}) + p^2_G \exp(-2P_{AB}) \quad .. \quad .. \quad (4.11)$$
$$q_{GABG} = q_{AB} - p_G(p_{AB} + p_{BA}) + p^2_G \exp(-2P_{AB}) \quad .. \quad .. \quad (4.12)$$

4.3. *Irregular Line with Small Impedance Deviations*

For a nominally homogeneous line OL of length l, we may define the average characteristic impedance Z_m as

$$Z_m = \frac{1}{l}\int_0^l Z_x dx \quad .. \quad .. \quad .. \quad (4.13)$$

Thus we may write

$$Z_x = Z_m + S_x \quad .. \quad .. \quad .. \quad (4.14)$$
$$= Z_r + \sigma_x \quad .. \quad .. \quad .. \quad (4.15)$$

where Z_r is a reference impedance sufficiently close to Z_m to make $(Z_r - Z_m)^2/Z_m^2$ negligible compared with 1; σ_x is the local deviation from this reference impedance, and S_x is the particular value of the deviation when the reference impedance is equal to the mean impedance.

Similarly for the nominally homogeneous line the average propagation coefficient per unit length, γ, is defined as

$$\gamma = \frac{1}{l}\int_0^l \gamma_x dx \quad .. \quad .. \quad .. \quad (4.16)$$

and $$\gamma_x = \gamma + g_x \quad .. \quad .. \quad .. \quad (4.17)$$

If σ_x/Z_x is small, then g_x/γ_x will be smaller. This follows because the principal deviations are due to inductance and capacitance variations, and these in turn are produced mainly by variations in conductor dimensions and in effective permittivity. The former produce local changes in L and C which to a first approximation add for Z_x but cancel for γ_x, and it is only changes in the dielectric which affect both Z_x and γ_x to the same degree.

Considering the line with one deviating portion discussed in Section (3.4), as the length of AB becomes progressively smaller and in the limit approaches dx, the propagation coefficient P_{AB} becomes $\gamma_x dx$. The reflection and transmission coefficients from (4.1) and (4.2) become

$$p_{AB} = 2p_x\gamma_x dx$$
$$= 2p_x\gamma dx \text{ (since } g_x/\gamma \text{ is small)} \quad (4.18)$$
$$m_{AB} = 1 - 2p^2{}_x\gamma dx \quad .. \quad .. \quad (4.19)$$

where $p_x = \sigma_x/2Z_r \quad .. \quad .. \quad .. \quad (4.20)$

An irregular line is composed of a large number of adjacent small portions such as AB, each contributing a term $2p_x \exp(-2P_{ox})dx$ to the reflection coefficient. Replacing P_{ox} by γx introduces a negligible error when g_x/γ is small, and thus for the irregular line, we have from (4.3)

$$p_r = \frac{\gamma}{Z_r}\int_0^l \sigma_x \exp(-2\gamma x)dx \quad .. \quad (4.21)$$

where p_r denotes the reflection coefficient with respect to Z_r. When the mean impedance is selected as reference impedance, p is written without a suffix as this is a frequent case, and we have

$$p = \frac{\gamma}{Z_m}\int_0^l S_x \exp(-2\gamma x)dx \quad (4.22)$$
$$= p_r + \frac{\Delta Z}{2Z_m}\{1 - \exp(-2\gamma l)\} \quad (4.23)$$

where $\Delta Z = Z_r - Z_m$.

Similarly for the transmission coefficient, we have from (4.6)

$$m_r = 1 - \frac{\gamma}{2Z^2{}_r}\int_0^l \sigma^2{}_x dx + \frac{\gamma^2}{Z^2{}_r}\int_0^l \sigma_x \exp(-2\gamma x)\int_0^x \sigma_T \exp(2\gamma y)dy\,dx$$
$$.. \quad .. \quad .. \quad (4.24)$$

or $$m = 1 - \frac{\gamma}{2Z^2{}_m}\int_0^l S^2{}_x dx + \frac{\gamma^2}{Z^2{}_m}\int_0^l S_x \exp(-2\gamma x)\int_0^x S_T \exp(2\gamma y)\,dy dx$$
$$.. \quad .. \quad .. \quad (4.25)$$

World Radio History

To appreciate the physical basis of the integral forms of the expressions for the reflection and transmission coefficients, we revert to the line built up of a number of adjacent deviating portions. From this it is apparent that equation (4.21) contains the reflection from a given point as the difference of two components, viz., the ordinates of the infinitesimal portions on either side of the point. For example, in considering the 'tail' of a television signal,[3,5] one computes the reflection coefficient due to irregularities situated at distances greater than a given value from the origin. If we divide p_r as given by equation (4.21) into two parts representing reflection from O to B ($x = b$) and from B to L, Fig. 7, we obtain

$$p_{OB} = \frac{\gamma}{2Z_r}\int_0^b \sigma_x \exp(-2\gamma x)dx \quad .. \quad (4.26a)$$

$$p_{BL} = \frac{\gamma}{2Z_r}\int_b^l \sigma_x \exp(-2\gamma x)dx \quad .. \quad (4.26b)$$

and have thereby added unnecessarily $-\sigma_B \exp(-2\gamma b)$ to equation (4.26a) and $+\sigma_B \exp(-2\gamma b)$ to equation (4.26b). For a physical division of the line, with termination of each part by Z_r, equations (4.26a) and (4.26b) would of course be correct. The difference is brought out by throwing equation (4.21) into an alternative form by integrating it by parts. Thus we obtain

$$p_r = \frac{1}{2Z_r}\left[\int_0^l \sigma'_x \exp(-2\gamma x)\,dx + \sigma_0 - \sigma_L \exp(-2\gamma l)\right] \quad (4.27)$$

where $\sigma'_x = \dfrac{\partial \sigma_x}{\partial x}$ and σ_0, σ_L are the values of the impedance deviations at the beginning and end of the line. On breaking up the reflection coefficient, the two parts corresponding to equations (4.26a) and (4.26b) are

$$p_{OB} = \frac{1}{2Z_r}\left[\sigma_0 + \int_0^b \sigma'_x \exp(-2\gamma x)\,dx\right] \quad (4.28a)$$

$$p_{BL} = \frac{1}{2Z_r}\left[\int_b^l \sigma'_x \exp(-2\gamma x)dx - \sigma_L \exp(-2\gamma l)\right] \quad .. \quad (4.28b)$$

and in this form no unnecessary terms are introduced. On the other hand, these expressions are not correct if the line is physically divided and each section is terminated by Z_r. To appreciate this aspect, we notice that in equation (4.27) the term $\sigma_0/2Z_r$ represents the reflection coefficient for the step between the generator and the entrance to the line, and $\sigma_L \exp(-2\gamma l)/2Z_r$ the reflection coefficient for the step between the end of the line and the terminal impedance.

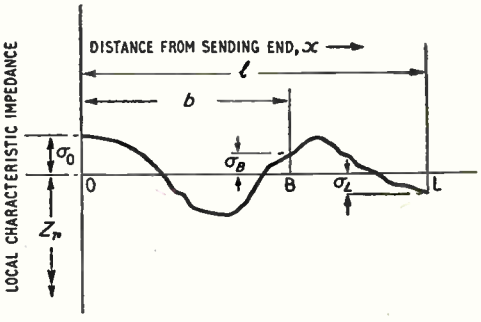


Fig. 7. *Variation of impedance along irregular line.*

Thus $\dfrac{1}{2Z_r}\int_0^l \sigma'_x \exp(-2\gamma x)\,dx$ represents the reflection coefficient of the line when the generator and terminal impedances are respectively equal to the impedances of the portions of line immediately adjacent to them. With an irregular line, these impedances are in practice indeterminate, as they depend on the length over which the impedance may be regarded as uniform, so that for measurement purposes it is usually preferable to use the form of equation (4.21).

Similar considerations apply to the integral form of the equation for the transmission coefficient. In equation (4.24) the interaction between adjacent infinitesimal portions is contained partly in the first term and partly in the second; furthermore the division into parts again introduces unnecessary terms. This may be avoided by throwing (4.24) into an alternative form by integrating by parts, when we obtain

$$m_r = 1 + \frac{1}{4Z_r^2}\left[\sigma_0\sigma_L \exp(-2\gamma l) - \tfrac{1}{2}(\sigma_0^2 + \sigma_L^2) - \sigma_0\int_0^l \sigma'_x \exp(-2\gamma x)dx + \sigma_L\int_0^l \sigma'_x \exp\{-2\gamma(l-x)\}\,dx - \int_0^l \sigma'_x \exp(-2\gamma x)\int_0^x \sigma'_r \exp(2\gamma y)dy\,dx\right] \quad (4.29)$$

Here the term $-\dfrac{1}{4Z_r^2}\int_0^l \sigma'_x \exp(-2\gamma x)\int_0^x \sigma'_r \exp(2\gamma y)dy\,dx$ represents the

World Radio History

transmitted echo coefficient when the generator and termination equal the respective impedances of the portions immediately adjacent to them.

Equation (4.27) may also be put into the form

$$p_T = \frac{1}{2Z_T}\sum_{x=0}^{x=L} \exp(-2\gamma x)\delta Z_x \quad .. \quad (4.30)$$

where δZ_x is the change of impedance at X, and the sum includes the steps at the beginning and end of the line. In this form, the equation is useful when we wish to consider the effects of abrupt changes of impedance.

5. Effect of Small Line Irregularities on the Open- and Short-Circuited Impedances

When a uniform line is open-circuited at its distant end, its input impedance is

$$Z_{op} = Z \coth \gamma l \quad .. \quad .. \quad .. \quad .. \quad (5.1)$$

When the distant-end is short-circuited, the input impedance becomes

$$Z_{sh} = Z \tanh \gamma l \quad .. \quad .. \quad .. \quad (5.2)$$

If a line AB has small irregularities and is terminated by an impedance Z_T, the input impedance is from equation (3.47)

$$Z_{AT} = Z_m\left[\frac{1 + p_{AB} + p_T \exp(-2\gamma l)/(1 - p_{BA}p_T)}{1 - p_{AB} - p_T \exp(-2\gamma l)/(1 - p_{BA}p_T)}\right] \quad .. \quad (5.3)$$

where p_{AB}, p_{BA}, are the reflection coefficients at A and B respectively with the distant end terminated by Z_m, and $p_T = (Z_T - Z_m)/(Z_T + Z_m)$. When the distant end is open, $p_T = +1$, and when it is closed $p_T = -1$. Thus the input impedance of an irregular line with the distant end open is

$$Z_{Aop} = Z_m\left[\frac{1 + p_{AB} + \exp(-2\gamma l)/(1 - p_{BA})}{1 - p_{AB} - \exp(-2\gamma l)/(1 - p_{BA})}\right] \quad .. \quad .. \quad .. \quad .. \quad (5.4)$$

When the distant end is closed, the input impedance becomes

$$Z_{Ash} = Z_m\left[\frac{1 + p_{AB} - \exp(-2\gamma l)/(1 + p_{BA})}{1 - p_{AB} + \exp(-2\gamma l)/(1 + p_{BA})}\right] \quad .. \quad .. \quad .. \quad .. \quad (5.5)$$

Provided $p_{AB} + p_{BA}$ is small compared with $1 - \exp(-2\gamma l)$, which is generally the case,

$$Z_{Aop} = Z_m \coth \gamma l\left[1 + \frac{p_{AB} + p_{BA}}{1 - \exp(-2\gamma l)} + \frac{p_{AB} - p_{BA}}{1 + \exp(-2\gamma l)}\right] \quad (5.6)$$

Similarly, provided $p_{AB} - p_{BA}$ is small compared with $1 + \exp(-2\gamma l)$,

$$Z_{Ash} = Z_m \tanh \gamma l\left[1 + \frac{p_{AB} + p_{BA}}{1 - \exp(-2\gamma l)} + \frac{p_{AB} - p_{BA}}{1 + \exp(-2\gamma l)}\right] \quad (5.7)$$

Thus a correction factor K_{AB} which gives the influence of irregularities on the open- and short-circuited input-impedances of the corresponding uniform line, is

$$K_{AB} = 1 + \frac{p_{AB} + p_{BA}}{1 - \exp(-2\gamma l)} + \frac{p_{AB} - p_{BA}}{1 + \exp(-2\gamma l)} \quad .. \quad .. \quad (5.8)$$

Equivalent formulae are quoted by Kaden,[2] and by Parcé,[7] but proofs are not given. Thus under these conditions, the apparent characteristic impedance is

$$Z' = \sqrt{Z_{Aop}Z_{Ash}} = Z_m K_{AB} \quad .. \quad .. \quad (5.9)$$

The apparent propagation coefficient is

$$P' = \tanh^{-1}\sqrt{Z_{Ash}/Z_{Aop}} = \gamma l \quad .. \quad .. \quad (5.10)$$

Hence when measuring by the 'open and closed' method, small line irregularities would have an appreciable effect on the apparent characteristic impedance, but none on the attenuation and phase-change coefficients. Caution is necessary, however, in applying the last conclusion to measurements made when the line is in resonance.

6. Conclusion

The Kennelly method of successive reflections has been shown to yield expressions by simple mathematical processes which are in agreement with those derived by more formal methods. The relative coefficients may be calculated and measured, and the results applied to the evaluation of the quality of irregular lines for the transmission of broad-band telephony and television, but the discussion of these topics is outside the scope of this paper.

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World Radio History

THE E-H SURFACE WAVE

By A. E. Karbowiak

SUMMARY—The basic formulae for the E-H surface wave (which is a mixture of two surface waves; the E- and H- modes) are given. The cylindrical guide that is conducting in a helical direction is analysed in detail and the canonical frequency equation is put into a very simple form by making suitable approximations. Finally, it is shown, that although a travelling E-H surface wave can be supported by a helically-conducting guide, it is not possible to have a pure E-H surface wave on a transmission line terminated by a short-circuiting plate. Yet two similar E-H surface waves travelling in opposite directions on the same line give rise to an elliptically-polarized surface wave.

1. Introduction

THE wave mode usually associated with a single-wire transmission line[1] is the E-mode that is evanescent over the wave front. This is a form of electromagnetic wave which propagates without radiation along the outside of a single cylindrical guide[6] and is characterized by the presence of an axial component of the electric field vector and absence of the longitudinal component of the magnetic field vector (E-mode). In the plane normal to the axis of the guide the electromagnetic field extends to infinity in the radial direction, but the energy density of the field decays monotonically with radial distance at a rate determined by the surface properties of the guide. At large distances from the guide the field quantities decay approximately exponentially and usually most of the energy of the wave is constrained to flow in the immediate neighbourhood of the guide. Such a field is called evanescent. The surface wave on the *outside* of the guide is often accompanied by a guided wave *inside* the guide which is not a surface wave but whose nature is a function of the physical configuration of the guide structure, and is irrelevant except in so far that it provides the necessary guide surface impedance. The performance of a single-wire transmission line is governed by its radial decay coefficient, and this depends solely on the guide radius and the surface impedance.[2,3] Of course, it is assumed that most of the power is carried on the outside of the guide and scarcely any on the inside. This $E_{0\times}$ mode (where $\times$ signifies evanescent nature of the wave in the radial direction) has been investigated in detail[2,3], and there are at least two distinct methods of decreasing the lateral spread of the field (i) by coating the wire with a layer of dielectric and (ii) by corrugating the surface of the guide.

It has been known for some time that a helix made of a conducting wire will support a wave mode which has found particular application in the travelling-wave valve[4]. The wave associated with this structure possesses axial components of both electric and magnetic field, and since the wave is evanescent over the wave front on the outside of the helix we shall call the wave mode exterior to the helix the E-H surface wave ($EH_{0\times}$ mode). Kaden[5] recognized the bearing of this type of wave on possible future development in ultra-high-frequency transmission lines and suggested the use of a stranded conductor for single-wire transmission lines. It is the purpose of this paper to present the basic formulae of the E-H surface wave and to investigate some of its characteristics when supported by a helically-conducting guide.

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2. Field Equations of the Progressive E-H Surface Wave

Let us describe the electromagnetic field in terms of the cylindrical co-ordinates: r, ϕ, z (Fig. 1). Assuming negligible losses the field outside the cylindrical guide radius s is derived from the wave function*

$$F_1(r,z) = \mathrm{H}_0^{(1)}(jur) \cdot e^{j(\omega t - \beta z)} \quad .. \quad (1)$$

where $\beta^2 - u^2 = k^2 = \omega^2\mu_0\kappa_0$ .. .. (2)

and u = radial propagation coefficient

β = axial propagation coefficient

$\mathrm{H}_n^{(1)}$ = Hankel function of order n

μ_0, κ_0 = permeability and permittivity of free-space respectively, in m.k.s. system of units.

Omitting the factor $e^{j(\omega t - \beta z)}$ the field components of the E-H surface wave become

$$\left.\begin{aligned} E_{z1} &= A_1\mathrm{H}_0^{(1)}(jur) \quad , \\ H_{z1} &= B_1\mathrm{H}_0^{(1)}(jur) \\ E_{r1} &= A_1\frac{\beta}{u}\mathrm{H}_1^{(1)}(jur) \quad , \\ H_{r1} &= B_1\frac{\beta}{u}\mathrm{H}_1^{(1)}(jur) \\ H_{\phi 1} &= A_1\frac{\omega\kappa_0}{u}\mathrm{H}_1^{(1)}(jur) \quad , \\ E_{\phi 1} &= -B_1\frac{\omega\mu_0}{u}\mathrm{H}_1^{(1)}\,jur) \end{aligned}\right\} \quad .. \quad .. \quad (3)$$

where A_1, B_1 are two independent constants.

Inside the guide (radius s) the electromagnetic

* Stratton, J. A. "Electromagnetic Theory" (McGraw-Hill), 1941, p. 360. Schelkunoff, S. A. "Electromagnetic Waves" (D. Van Nostrand Co.), 1943, p. 406.

World Radio History

field is derived from the wave function

$$F_2(r,z) = J_0(hr) \cdot e^{j(\omega t - \beta z)} \quad \ldots \quad (4)$$

where $\beta^2 + h^2 = k_1^2 = \omega^2\mu_1\kappa_1$ . . . . . (5)

and h = radial propagation coefficient

μ_1, κ_1 = permeability and permittivity of the dielectric inside the guide

J_n = Bessel function of order n.

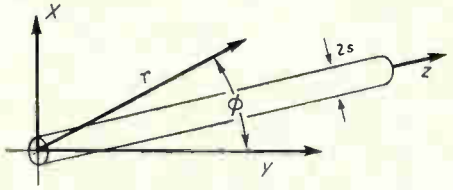

Fig. 1. *The co-ordinate system.*

The field components inside the guide will thus become (the exponential factor is understood);

$$\left.\begin{aligned} E_{z2} &= A_2 J_0(hr) \\ H_{z2} &= B_2 J_0(hr) \\ E_{r2} &= A_2 \frac{j\beta}{h} J_1(hr) \\ H_{r2} &= B_2 \frac{j\beta}{h} J_1(hr) \\ H_{\phi 2} &= A_2 \frac{\omega j \kappa_0}{h} J_1(hr) \\ E_{\phi 2} &= -B_2 \frac{j\omega\mu}{h} J_1(hr) \end{aligned}\right\} \quad \ldots \quad (6)$$

where A_2, B_2 are two different constants.

The particular relation between the constants A_1, B_1 and A_2, B_2 will depend on the nature of the guide but, whatever these constants are, the equations (3) represent the field of an E-H surface wave provided u lies in the fourth quadrant of the Argand diagram.[2,3] If $B_1 = 0$ then the remaining equations of (3) represent a pure E-surface wave and if $A_1 = 0$ then (3) represents an H-surface wave. It is essential for the existence of the H-surface wave that the lines of magnetic field strength shall penetrate the guide surface. The field thus can be evanescent on the outside of the guide and yet lines of magnetic field strength form closed loops in the plane containing the guide axis.

3. The Helically-Conducting Guide

Suppose that the guide is conducting in the helical direction ψ as shown in Fig. 2, and non-conducting in the direction normal to this. Thus the boundary conditions to be imposed on (3) and (5) are:—

(i) The tangential electric field must be continuous across the guide surface; i.e.,

$$\left.\begin{aligned} E_{z1} &= E_{z2} \quad (r = s) \\ E_{\phi 1} &= E_{\phi 2} \quad (r = s) \end{aligned}\right\} \quad \ldots \quad (7)$$

(ii) There is no electric field strength at the surface of the guide in the conducting direction; thus

$$\left.\begin{aligned} E_{z1}\sin\psi + E_{\phi 1}\cos\psi &= 0 \quad (r = s + 0) \\ E_{z2}\sin\psi + E_{\phi 2}\cos\psi &= 0 \quad (r = s - 0) \end{aligned}\right\} \quad (8)$$

(iii) The component of magnetic field strength in the direction of the helix must be continuous across the guide surface; thus

$$H_{z1}\sin\psi + H_{\phi 1}\cos\psi = H_{z2}\sin\psi + H_{\phi 2}\cos\psi \quad (r = s) \quad \ldots \quad (9)$$

Relations (7), (8) and (9) lead to four independent equations involving the coefficients A_1, B_1 and A_2, B_2 wherefrom upon elimination we obtain the equation

$$\frac{H_0^{(1)}(jus)J_0(hs)}{H_1^{(1)}(jus)J_1(hs)} \times \frac{uh}{j\omega^2\mu_1\kappa_1} = \chi\cot^2\psi \quad \ldots \quad (10)$$

where

$$\chi = \frac{us\dfrac{H_0^{(1)}(jus)}{H_1^{(1)}(jus)} + j\frac{\kappa_0}{\kappa}.hs.\dfrac{J_0(hs)}{J_1(hs)}}{us\dfrac{H_0^{(1)}(jus)}{H_1^{(1)}(jus)} + j\,.\,hs.\dfrac{J_0(hs)}{J_1(hs)}} \quad \ldots \quad (11)$$

and, from (2) and (5)

$$h^2 + u^2 = \omega^2\mu(\kappa_1 - \kappa_0) \quad \ldots \quad (12)$$

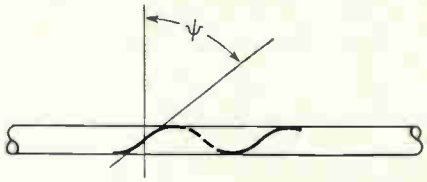

Fig. 2. *Cylindrical guide conducting in the direction of a helix.*

Thus, given the radius of the guide and the lay of the helix then from equations (10)–(12) the decay coefficient u could in principle be calculated; however, it is a laborious procedure. If $\kappa_1 = \kappa_0$ as in a travelling-wave valve[4] then $\chi = 1$ and (10) could be solved by graphical means. But if the guide were made by winding a bunch of wires in a helical manner around the circumference of a dielectric rod then, of course, $\kappa_1 \neq \kappa_0$ and a different approach would be necessary. The expression (10) simplifies notably if we assume that the guide radius is small and that the decay coefficient is small in comparison with h. We then obtain $\chi = \kappa_0/\kappa_1$ and the frequency equation (10) becomes

$$\frac{H_0^{(1)}(jus)J_0(hs)}{H_1^{(1)}(jus)J_1(hs)}\,uh = jk_0^2\cot^2\psi \quad \ldots \quad (13)$$

This equation could be solved for u graphically

World Radio History

but at this stage further approximations are legitimate. We may take

$$h \approx h_0 = \omega\sqrt{\mu(\kappa_1 - \kappa_0)} \quad .. \quad .. \quad (14)$$

and replace the Hankel functions occurring in (13) by their small argument approximations :

$$\left.\begin{aligned} \text{Thus :—} \quad H_0^{(1)}(jus) &\approx j\frac{2}{\pi}\log_e(0{\cdot}89us) \\ H_1^{(1)}(jus) &\approx -\frac{2}{\pi us} \end{aligned}\right\} \quad (15)$$

With these simplifications (13) reduces to

$$\xi \log_e \xi = -(0{\cdot}89)^2 \frac{J_1(h_0 s)}{J_0(h_0 s)} \cdot \frac{(k_0 s \cot\psi)^2}{h_0 s} \quad .. \quad (16)$$

where[2],[3] $\xi = (0{\cdot}89us)^2$

Now, the fundamental equation is[2]

$$\xi \log_e \xi = \eta \quad .. \quad .. \quad .. \quad .. \quad (17)$$

where

$$\eta = -2{\cdot}(0{\cdot}89)^2 k_0^2 s x_s \quad .. \quad .. \quad (18)$$

X_s = surface reactance of a guide carrying an E surface wave

and

$$Z_0 = \sqrt{\mu_0/\kappa_0} = 377 \text{ ohms.}$$

Thus, equating (16) and (18) we get

$$X_s = \frac{1}{2}\frac{Z_0}{\sqrt{1 - \kappa_0/\kappa}} \cdot \frac{J_1(h_0 s)}{J_0(h_0 s)} \cot^2\psi \quad (\kappa_0 \neq \kappa_1) \quad .. \quad (19)$$

and

$$X_s = \frac{Z_0}{4} k_0 s \cot\psi \quad \text{if } \kappa_1 = \kappa_0 \quad .. \quad .. \quad (20)$$

We shall refer to (19) and (20) as the equivalent surface reactance of a helically-conducting guide. These formulae are simple to use and curves shown in Fig. 3 were calculated using equation (20).

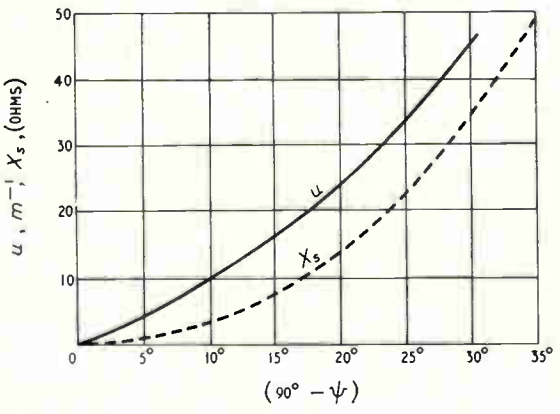

Fig. 3. *The radial propagation coefficient u and the surface reactance X_s as a function of the lay angle ψ.*

4. The E-H Surface Wave other than Progressive

In Section 2 we have established the possible existence of a progressive E-H surface wave. In practical applications, however, more often than not a partial standing wave will be encountered. We shall next enquire what is the field distribution of an E-H surface wave supported by a transmission line short-circuited at one end. Suppose the short-circuit occurs at $z = 0$ then the boundary condition to be satisfied at this point is $E_r(r,0) = E_\phi(r,0) = 0$ .. .. .. (21)

while the boundary condition to be satisfied at the surface of the guide is

$$E_{\phi_1}(s, z) = \tau E_{z1}(s, z) \quad .. \quad .. \quad (22)$$

where τ is a factor depending on the nature of the guide.* It is not difficult to show that the boundary conditions (21) and (22) cannot be simultaneously satisfied. The inference can be drawn that a *pure* E-H surface wave may exist as a travelling wave, but is not possible on a short-circuited transmission line. The physical reason for this is that a 'right-handed' E-H surface wave (surface wave supported by a right-handed helix) is reflected from a short-circuiting plate as a 'left-handed' E-H surface wave (capable of being supported by a left-handed helix) and this cannot be supported by a right-handed helical guide necessary for the support of the outgoing wave.

Nevertheless it is possible, at least mathematically, to have two right-handed/left-handed E-H surface waves travelling in opposite directions on a right-handed/left-handed helical guide, but the resultant field does not possess the character of a standing wave (where the transverse component of the electric vector exhibits successive nodes and anti-nodes). This field is an elliptically polarized E-H surface wave whose plane of polarization is turning clockwise/anti-clockwise with respect to an observer moving along the line.

Acknowledgments

The author acknowledges gratefully helpful discussions with Professor H. M. Barlow and Dr. A. L. Cullen of University College, London.

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* In the case of the helical guide it takes the form given by (8); i.e., $\tau = \tan\psi$.

World Radio History

TAPPED INDUCTANCES

Calculation of Tapping Points

By C. R. Cosens, M.A.

INDUCTORS for use at audio-frequencies are conveniently wound as 'Maxwell coils'; i.e., they are circular coils of square cross-section, such that the inner diameter of the coil is twice the side of the square. It is sometimes desirable to provide tappings at specified fractions of the total inductance, and it is the object of this note to derive a simple method of calculating at what fraction n of the total turns a tapping must be made in order that the inductance measured between the inner end of the winding and the tapping shall be a specified fraction l of the inductance of the whole Maxwell coil. The simple formulae derived give an accuracy of 3 parts in 1,000, without reference to tables; they are based on equations and tables in Chapter 13 of F. W. Grover's "Inductance Calculations," Van Nostrand, New York, 1946.

From equation (94) of this chapter we find that the inductance L_M (microhenrys) of a complete Maxwell coil of width b (cm), having N_M turns, is given by:

$$L_M = 0{\cdot}02549\ N_M^2 \times b \quad \ldots \quad (1)$$

whence, putting τ = number of turns per sq. cm. of cross-section,

$$b = 2{\cdot}083 \times (L_M/\tau)^{1/5} \quad \ldots \quad (2)$$

and then $N_M = \tau b^2 \quad \ldots \quad (3)$

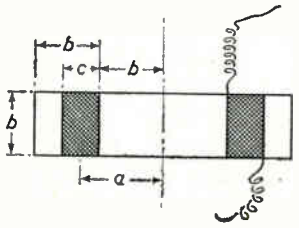

Fig. 1. *Sectional view of coil considered; full Maxwell coil shown in outline.*

The inductance of any circular coil of rectangular cross-section can be found in terms of the three dimensions a, b and c shown in Fig. 1, and of the turns N. For the special case of part of a Maxwell coil, from the inner end to the tapping, $2a = 2b + c$, or $2a/b = 2 + c/b$ (since the inner diameter of the coil is $2b$). The turns $N = \tau bc$, but for the whole Maxwell coil, to which the suffix $_M$ refers, $c_M = b$, so $N_M = \tau b^2$, hence $n = N/N_M = c/b$. It follows that the ratios

$$c/b = n,\ 2a/b = (n+2),\ \text{and}\ c/2a = n/(n+2) \quad (4)$$

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can all be expressed in terms of the single variable n.

In terms of these ratios, Grover's Table 36 gives K ('Nagaoka's constant'), which takes account of the axial separation of the turns; and double-entry tables 22-25 give k, which takes account of their radial separation. Tabulating, to four decimals, to argument $n = 0{\cdot}0\ (0{\cdot}1)\ 1{\cdot}3$, these ratios, K, k, and $K' = K - k$, we have, from equation 99 (omitting a constant multiplier)

$$L \propto N^2 \times \left(2\frac{a}{b}\right) \times a \times K'$$

$$\text{or}\ \frac{2L}{b} \propto N^2 \times \left(2\frac{a}{b}\right)^2 \times K' = N^2[(n+2)^2 K'] \quad (5)$$

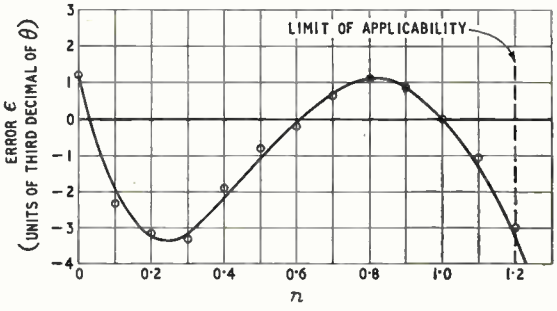

Fig. 2. *Error curve for the value of θ.*

For the complete Maxwell coil the square bracket [ ] is a constant, say β so that equation (5) gives $2L_M/b \propto N_M^2\beta$, and hence

$$l = \frac{L}{L_M} = \left(\frac{N}{N_M}\right)^2 \times [(n+2)^2 K']/\beta = n^2\phi, \quad (6)$$

say, where the numerical value of β is to be determined so that $\phi = [(n+2)^2\ K']/\beta$ shall equal 1 when $n = 1$, $l = 1$.

After some tedious computing we have a table of ϕ to argument n. But no table is satisfactory unless it can easily be interpolated; tables relating ϕ to l, n or n^2 all offer interpolation difficulties near zero, where the differences are not only large, but apparently divergent. The trouble is overcome if instead of ϕ we tabulate its reciprocal $\theta = 1/\phi$ to argument n. Having tabulated to four decimals, we round θ to three, and find, somewhat surprisingly, that we only incur errors between $+1$ and -3 in the third decimal place if we write $\theta = 1 + 0{\cdot}230\,(1 - n)$, where $0 < n < 1{\cdot}2$; $0 < l < 1{\cdot}5$ (7)

World Radio History

Since over this range $1{\cdot}23 > \theta > 0{\cdot}98$, the error is less than 3 in 1,000.

Then $l = n^2/\theta$, or $n = \sqrt{l\theta}$ . . . . . (8)

When seeking n for given l, we can avoid the solution of a cubic in n by using the method of iteration, thus:

$$n_0 = \sqrt{l},\ \theta_r = 1 + 0{\cdot}230(1 - n_r),\ n_{r+1} = \sqrt{l\theta_r}\ (9)$$

Convergence is rapid, n_4 nowhere differs from n_3 by more than half a unit in the third decimal place.

(Values of n and l greater than unity obviously refer to a coil having additional turns wound over and above those of a true Maxwell coil, this may sometimes be convenient.)

It may be of some slight (though purely academic) interest, to plot the errors of the empirical formula $\theta = 1 + 0{\cdot}230\ (1 - n)$. This is shown in Fig. 2 where

ϵ = (empirical) — (computed from Grover).

Since only four decimals and linear interpolation in Grover's tables were written throughout, plotted points may be expected to be unreliable within about $\pm 0{\cdot}03$.

The shape of the curve is strongly reminiscent of a cubic, with zero quadratic term. This suggests the possibility that if θ, defined as n^2/l, could be expanded in ascending powers of n, from the theoretical formulae used by Grover to compute his tables (they are not specified, presumably combinations of elliptic integrals) the coefficient of n^2 in the expansion $\theta = a + bn + cn^2 + dn^3 + \ldots$ would be found to vanish. This would explain the unexpected closeness of the linear approximation $\theta \approx 1 + 0{\cdot}230\ (1 - n)$ [better than 3 parts in 1,000]. Admittedly this is a shot in the dark.

For practical purposes, of course, since the number of turns will not, in general, form complete layers, as the formula assumes, accuracy better than $\pm 1\%$ would be quite illusory.

CORRESPONDENCE

Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Output Impedance Theorem

SIR,—I have noticed the great interest of *Wireless Engineer* in new circuit theorems, and I therefore submit the following:—

In the general case when a constant-voltage generator, c.v.g. or e.m.f., or a constant-current generator, c.c.g., in the equivalent circuit described by Thévenin or Norton, is independent of a voltage applied to the terminals AB of the equivalent circuit, the output impedance is defined as the inner impedance, with the added series or parallel impedance, contributed by the equivalent c.v.g. or c.c.g., interpreted as an impedance with the aid of the compensation theorem.

When the internal c.v.g. or c.c.g. is a function of the applied voltage V_{AB}, and proportional to it, this relation may be expressed via a known proportionality constant k. It is then possible to write down directly the output impedance Z_{AB}, if use is made of a new theorem, which has the form:

Theorem: If in a linear, active, one-pair terminal network, described by Thévenin's or Norton's theorems, the c.v.g. or the series injected voltage from the c.c.g., is proportional to the voltage V_{AB} applied to the terminals AB, and k times V_{AB}, the output impedance is the passive network output impedance, divided by $(k + 1)$.

A passive network obtains when all c.v.gs are short-circuited, and all c.c.gs open-circuited. This theorem makes unnecessary the in-between application of the compensation theorem (which application is usually made unconsciously, anyhow), and yields the answer more or less directly.

As an example, consider a simple cathode follower, Fig. 1(a), with its series equivalent circuit in Fig. 1(b), which is a Thévenin circuit. Since $k = \mu$, the above theorem states that $Z_{AB} = r_a/(\mu + 1)$, which is the correct result. If the parallel equivalent circuit for a cathode follower is used or, alternatively, the circuit used that results when the voltage source in Fig. 1(b) is represented as a current source, the Norton circuit in Fig. 1(c) results. Then the 'series injected' voltage from the c.c.g. is $(\mu V_{AB}\, r_a) \div r_a = \mu V_{AB}$, thus $k = \mu$, and as before $Z_{AB} = r_a/(\mu + 1)$. Since in many feedback

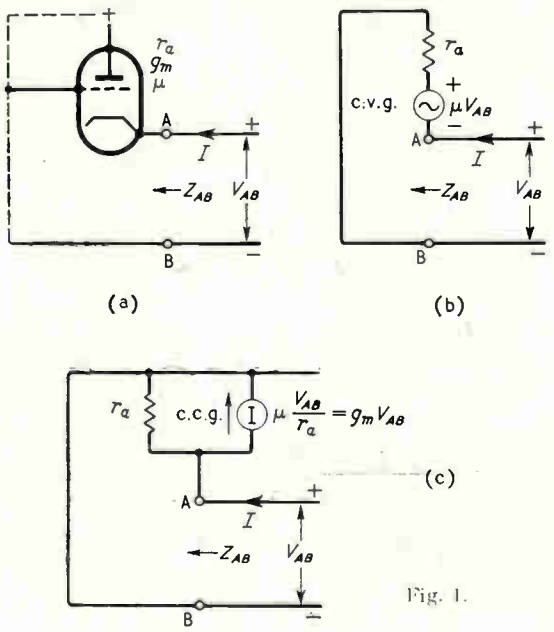

Fig. 1.

World Radio History

circuits k, or the general form of k, is known, Z_{AB} can be written down upon inspection, not necessitating calculation.

With reference to this theorem, I take the liberty to call to general attention the unfortunate fact that not only are there about as many formulations of Thévenin's and Norton's theorems as there are languages, but within each language, such as the English, there are about a dozen different wordings of each theorem. In so far as different languages permit, not only could one single formulation of each theorem be agreed upon, but actually *only one formulation for both of them*. Thus the "Thévenin-Norton theorem," (perhaps in the future called "*the General Theorem of the Equivalent Source*"), would read:

Theorem: A linear, active, one-pair terminal network providing between its terminals AB the open circuit voltage V_{AB}, or short-circuit current I, may be replaced by an *equivalent source* of impedance Z_{AB}, which is the passive network looking-in impedance through the terminal pair, provided with the series c.v.g. V_{AB}, or shunt c.c.g. I.

There are other pairs of network theorems which may be 'internationalized,' standardized, and unified, into c.v.g.-c.c.g. formulation in accordance with the principle indicated above.

HARRY STOCKMAN.

Scientific Specialties Corporation,
Boston 35, Massachusetts, U.S.A.
28th December 1953.

A Circuit Problem

SIR,—In a letter by R. N. Bracewell,[1] which appeared in the January issue of this journal, attention was drawn to the following electric circuit problem: To connect the smallest possible number of 1-ohm resistors into a two-terminal network in such a way that no two resistors carry equal currents and so that the resistance of the combination is 1 ohm. The trivial case of one single resistor is excluded.

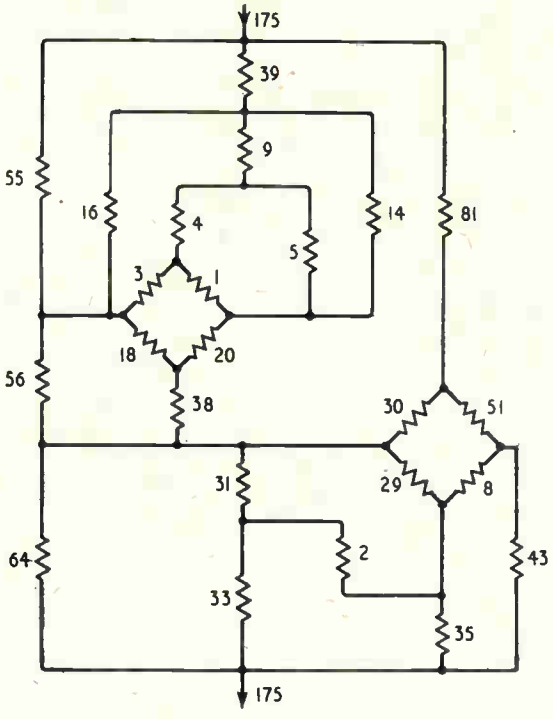

Fig. 1.

Although the solution of this curious problem is unknown to me, I should like to point out that it is not identical with the network given by Bracewell. His network, consisting of 26 resistors, is in fact a re-drawing of a planar graph equivalent to the perfectly squared square of Fig. 9 in a paper[2] cited by Bracewell, which at that time (1940) was the simplest known. Since then, T. H. Willcocks[3], of Bristol, has constructed such a square of order 24. The corresponding network is shown in Fig. 1, built up from only 24 resistors, that is, two less than in Bracewell's case.

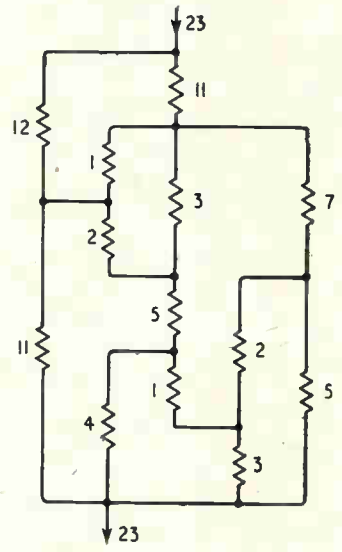

Fig. 2.

Some time ago I solved an analogous but simpler problem[4]: To connect the smallest possible number of 1-ohm resistors into a planar two-terminal network without series or parallel connections or zero currents so that the resistance of the combination is 1 ohm. This smallest number is 13. One of the two solutions to the second problem is shown in Fig. 2; the alternative is the dual of Fig. 2.

The numbers in Figs. 1 and 2 denote relative values of currents.

C. J. BOUWKAMP.

Philips Research Laboratories,
Eindhoven, Holland.
10th January, 1954.

[1] R. N. Bracewell, *Wireless Engr*, January 1954, Vol. 31, p. 27.

[2] R. L. Brooks, C. A. B. Smith, A. H. Stone and W. T. Tutte, *Duke math. J.* 1940, Vol. 7, pp. 312-340.

[3] T. H. Willcocks, *Fairy Chess Rev.*, Aug./Oct. 1948, Vol. 7, *Canad. J. Math.*, 1951, Vol. 3, pp. 304-308.

[4] C. J. Bouwkamp, *Proc. kon. ned. Akad. Wet. Amst.*, 1946, Vol. 49, pp. 1176-1188, Ibid., 1947, Vol. 50, pp. 58-78, pp. 1296-1299.

"WIRELESS ENGINEER" INDEXES

The annual indexes for 1953, both to *Wireless Engineer* articles and to Abstracts and References, are included in this issue. They are placed at the end so that by opening the staples they can readily be removed for binding with the 1953 Volume.

When binding, it is usually most convenient to separate the editorial and abstracts pages of each issue and to assemble them together in two blocks. The order of assembly for binding should then be: Index to Articles and Authors, all Editorial pages, all Abstracts pages, Index to Abstracts. It has been found that this grouping considerably facilitates reference.

World Radio History

NEW BOOKS

Probability and Information Theory, with Applications to Radar

By P. M. Woodward, B.A. Pergamon Press, Ltd., 242 Marylebone Road., London, N.W.1. Pp. 128 + x. Price 21s.

This book is one of the Pergamon Science series of monographs under the general title of 'Electronics and Waves' and under the general editorship of D. W. Fry of Harwell. Mr. Woodward is a mathematician in the Theoretical Physics division of the Telecommunications Research Establishment at Malvern. He is a well-known expert on communication theory, and has a marked ability to explain a point clearly and concisely in a lecture or discussion. The same clarity pervades much of the writing of the present book, which is intended to explain the theory by easy stages for the reader who has no highly advanced mathematical knowledge but wishes to link practical intuition and experience with mathematical theory. The illustrative numerical examples are excellent; by following them in detail, the reader can be sure that he has grasped the application of basic principles to artificially simple cases.

But in order that the book could be published quickly and at a reasonable price, it has had to be drastically condensed. It is a very fine achievement by Mr. Woodward to have produced at all a book of 125 pages which covers in essence so much ground. At the same time there is necessarily a hard core of mathematics for which this condensation may tend to decrease an engineer's initially insufficient mathematical confidence in himself. Key steps by which relevant results can be derived from Mr. Woodward's equations are indicated, but the significance of some equations is not easy to grasp. This is especially true where the equations are in an unfamiliar form because Mr. Woodward has neatly and usefully introduced certain new functions.

The first two chapters are concerned with probability theory, waveform analysis and noise. "They provide the code in which so much of the mathematical theory of electronics and radar is nowadays expressed." Chapter 3 is a summary of Shannon's original work[1]. Chapter 4 is concerned with the reception of a signal in noise by a communication system, while Chapter 5 is concerned with radar reception. Chapter 6, dealing with the mathematical analysis of radar information, is a revised account of work carried out by Mr. Woodward in partnership with Mr. I. L. Davies[2]. In Chapter 7 the transmitted radar signal is considered for a stationary target.

Information theory is by its essential nature a mathematical subject, and this fact must be faced by anyone interested; Mr. Woodward's book is a great help to those who are capable of facing it. J. W. H.

[1] "The Mathematical Theory of Communication", by C. E. Shannon and W. Weaver. Urbana: University of Illinois Press, 1949.
[2] *Phil. Mag.*, 1950, Vol. 41, p. 1001, and *Proc. Instn elect. Engrs* (Part III), 1952, Vol. 99, p. 37.

Fundamentals of Electronic Motion

By Willis W. Harman. Pp. 319 + x. McGraw-Hill Publishing Co., Ltd., 95 Farringdon Street, London, E.C.4. Price 46s. 6d.

In a lengthy preface the author, who is Associate Professor of Electrical Engineering at Stanford University, says that this is a book on analysis and that "the fact that it is written about electron tubes is to a certain extent incidental." Furthermore, he says that "Many educators feel that the answer to the problem imposed by the fabulously increasing body of engineering knowledge is increased concentration on general philosophies, understandings and attitudes, with correspondingly decreased emphasis on current engineering practice and specific design techniques. This book is written in that spirit." The author goes on to say that electron-tube analysis best demonstrates the philosophies and techniques of mathematical physics, for "particle dynamics, electromagnetic fields, and wave phenomena are all represented". His primary object is "to nurture the ability to deal with new problems and new situations".

He intends the book for the user of electron tubes: to give a general understanding rather than specialized information. The presentation is mathematical, but the author claims that no initial knowledge of mathematics beyond the calculus is necessary. Other mathematical techniques are explained as they are needed.

Chapter 1 covers the basic laws of electric and magnetic fields and their mathematical expression in the form of partial differential equations. These are in the curl, div, grad form and include the Laplace and Poisson equations. Approximate methods of field determination are also treated.

Chapter 2 deals with the motion of an electron in a static electric field and includes electron lenses. Chapter 3 is entitled "Electron Properties and Sources". Starting with the electron microscope, one proceeds through a discussion on electron diffraction, the electron as a wave packet and electron motion in solids to thermionic emission. Next, in Chapter 4, comes electron motion in a magnetic field, and in Chapter 5, negative and positive space charge. Chapters on motion in time-varying fields, space-charge waves and velocity modulation, travelling-wave amplification, magnetrons, and relativistic electrodynamics follow.

The book is not easy reading. It is one for study and it has its limitations although, within those limitations, it is very good. Its most valuable feature is the way in which problems are translated into mathematical form. This is where the novice usually runs into difficulty. Occasionally, a somewhat greater clarity of explanation would be desirable but, usually, this is all very well done.

It is also a good point that the solution of the resulting equations is carried out fairly fully. Since this is not a mathematical textbook, the author might have been forgiven for omitting this aspect. It is a fact, however, that it is much easier to learn mathematics in conjunction with an application of them than in the dreadfully arid atmosphere of the usual mathematics book. It is to the author's credit that he has evidently realized this.

On the whole, the author has done very well what he set out to do and has produced a very useful book. The student should be warned that in many cases things are not as simple as they are made to appear and one must disagree with the author's statement that the book is for "the user of electron tubes". In the ordinary meaning of these words the book is not for the user. It is for a rather specialized class of user who must know a great deal about what goes on inside a valve (and even this class will find it incomplete) but it is much more a basic textbook for the budding valve designer, who again will have to supplement it with a great deal of more technological material. W. T. C.

Relays for Electronic and Industrial Control

By R. C. Walker, B.Sc.(Lond.), A.M.I.Mech.E., A.M.I.E.E. Pp. 303 + xi. Chapman & Hall, Ltd., 37 Essex Street, Strand, London, W.C.2. Price 42s.

The opening words of the author's preface well explain the scope of this book; they are:—"The object of this book is to bring together in collected form for

World Radio History

handy reference the principal features and potentialities of relays as switching devices". Although quite a lot of information about the mechanical and electrical sides of actual relays is included, the book is not so much for the designer of relays as for the designer of equipment which incorporates them. In spite of this, there is a great deal of information about the magnetic circuit, forms of contact, temperature rise of coils and so on.

The treatment is descriptive rather than analytic and is largely non-mathematical, but not entirely so.

W. T. C.

Data and Circuits of Television Receiver Valves

By J. JAGER. Pp. 216 + xi. Book IIIc of "Electronic Valves" in the Philips Technical Library. Cleaver Hume Press Ltd., Wright's Lane, Kensington, London, W.8. Price 21s.

A major part of this book comprises data on valves, types ECC81, EF80, EB91, PL83, PL82, ECL80, PL81, PY80, PY81, PY82, EY51, and c.r. tubes, types MW36-44, MW36-24 and MW43-43. The data are of similar type to those given in valve-makers' catalogues but are much more comprehensive.

In addition, there are several pages of text for each valve in which its television applications are described and typical circuits are given. The practice described is continental, with f.m. sound and negative modulation, so that certain parts of it are inapplicable to British television, in particular the detector and video circuits.

Static Electrification

Pp. 104 + iv. The Institute of Physics, 47 Belgrave Square, London, S.W.1. Price 25s.

Twenty-four papers presented at a Symposium held by the Institute of Physics on 25th-27th March, 1953.

PREMIUMS FOR TECHNICAL WRITING

The Radio Industry Council has announced that six further premiums for technical writing have been awarded. They are of 25 guineas each to:—

G. G. Gouriet, A.M.I.E.E., for his article "Spectrum Equalization" which appeared in *Wireless Engineer*, May 1953.

A. W. Keen, M.I.R.E., A.M.I.E.E., for his article "Triode Transformation Groups", *Wireless Engineer*, October 1953.

A. H. Beck, B.Sc.(Eng.), A.M.I.E.E., and A. D. Brisbane, for their article "A Cylindrical Magnetron Ionization Gauge", *Vacuum*, April 1953.

D. McMullan, M.A., Ph.D., for his article "The Scanning Electron Microscope and the Electron-Optical Examination of Surfaces", *Electronic Engineering*, February 1953.

H. M. Davis, B.Sc., A.R.I.C., and Joyce Seaborn, B.Sc., for their article "A Linear Sweep Cathode-Ray Polarograph", *Electronic Engineering*, August 1953.

J. R. Pollard, M.A., M.I.E.E., M.I.R.E., for his article "Selective Calling for Radio-Telephone Systems", *Electronic Engineering*, December 1953.

The presentation of the awards is to be made at a luncheon of the Public Relations Committee of the Radio Industry Council on 11th March 1954.

MEETINGS

I.E.E.

10th March. "A Study of some of the Properties of Matter affecting Valve Reliability", by E. A. O'Donnell Roberts, M.Sc., Ph.D.

22nd March. "Colour Television", by C. J. Hirsch.

23rd March. "An Experimental and Theoretical Approach to the Teaching of Electromagnetism using the Rationalized M.K.S. System", by F. A. Meier, M.A., at 6 o'clock.

5th April. "Technical Problems involved in Receiving Alternative Television Programmes", discussion to be opened by F. R. W. Strafford and K. I. Jones.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, and will commence at 5.30 except where otherwise stated.

Brit.I.R.E.

31st March. "Radio Astronomy", by R. Hanbury Brown, to be held at London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.2, commencing at 6.30.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for January 1954

Date 1954 Jan.	Frequency deviation from nominal: parts in 10^8		Lead of MSF impulses on GBR 1000 G.M.T. time signal in milliseconds
	MSF 60 kc/s 1429-1530 G.M.T.	Droitwich 200 kc/s 1030 G.M.T.	
1	−1·2	+4	−18·5
2	N.M.	+5	N.M.
3	N.M.	N.M.	N.M.
4	−1·2	+4	−22·3
5	−1·3	+5	−23·3
6	−1·2	+6	−25·2
7	−1·3	+6	−27·4
8 *	—	+1	—
9	1·1	0	N.M.
10	−1·3	+1	N.M.
11	−1·2	+1	−32·9
12	−1·3	+1	−34·0
13	N.M.	+2	−36·2
14	−1·3	+1	−38·1
15	N.M.	+2	−39·0
16	N.M.	+2	−41·6
17	−1·0	+2	−42·7
18	−1·1	+1	−44·6
19	N.M.	+3	−46·0
20	−1·1	+2	−46·7
21	−1·1	+2	−49·3
22	−1·1	+1	−51·0
23	−1·1	−2	N.M.
24	−1·0	+2	N.M.
25	−1·0	+5	−54·3
26	−1·0	+6	−55·5
27	−1·0	+6	−57·1
28	−1·0	+6	N.M.
29	−1·1	+6	−59·9
30	−1·1	0	N.M.
31	−1·0	−1	N.M.

The values are based on astronomical data available on 1st February 1954.

The transmitter employed for the 60-kc/s signal is sometimes required for another service.

N.M. = Not Measured. * = No MSF Transmission.

World Radio History

ABSTRACTS and REFERENCES

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research and published by arrangement with that Department.

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses.

	PAGE A
Acoustics and Audio Frequencies	45
Aerials and Transmission Lines	46
Automatic Computers	47
Circuits and Circuit Elements	47
General Physics	51
Geophysical and Extraterrestrial Phenomena	52
Location and Aids to Navigation	54
Materials and Subsidiary Techniques	55
Mathematics	58
Measurements and Test Gear	58
Other Applications of Radio and Electronics	60
Propagation of Waves	61
Reception	61
Stations and Communication Systems	61
Subsidiary Apparatus	62
Television and Phototelegraphy	63
Transmission	64
Valves and Thermionics	64

ACOUSTICS AND AUDIO FREQUENCIES

534.213.4 **611**

The Transient Motion of Sound Waves in Tubes.—J. D. Pearson. (*Quart. J. Mech. appl. Math.*, Sept. 1953, Vol. 6, Part 3, pp. 313–335.) Using Heaviside operators, a formula is obtained for the velocity potential in an infinite tube of uniform cross-section, and an asymptotic solution is derived by the method of steepest descent. For a tube of slightly variable cross-section a series solution is obtained. The case of a tube of nearly rectangular cross-section with a longitudinal harmonic distortion is considered in detail.

534.213.4 : 534.61 **612**

Experiments on the Propagation of Plane Sound Waves in Tubes.—D. E. Weston & I. D. Campbell. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 769–774.) For measurements in the adiabatic region an acoustic interferometer was used, with a magnetostriction source. Values of attenuation and velocity were determined with tubes of radius 0·013 cm and upward, at frequencies from 10 to 20 kc/s, for various tube materials and gases. The results confirm the modified Kirchhoff's formula. For the transition region between adiabatic and isothermal flow, measurements were made with tubes of radius 0·02 cm. The attenuation results are a little higher than the calculated values, the velocity results are in general agreement with theoretical values.

534.4 : 534.78 **613**

Speech Communication Research.—G. Fant. (*IVA, Stockholm*, 1953, Vol. 24, No. 8, pp. 331–337. In English.) The formation of a speech-communication research group of the Division of Telegraphy and Telephony of the Swedish Royal Institute of Technology is announced and an outline is given of its programme, which covers both engineering and linguistic aspects. Methods for measuring the efficiency of communication systems for handling messages in Swedish are being studied.

534.6 : 534.321.9 **614**

Acoustic-Optical Image Conversion.—G. Spengler. (*NachrTech.*, Sept. 1953, Vol. 3, No. 9, pp. 399–402.) A survey is made of the principal methods used in the visual presentation of sound and ultrasonic fields in solids, liquids and gases. The characteristics of an ideal converter system are discussed and the problem of eliminating spurious effects due to reflections from the converter is considered.

534.614 **615**

The Velocity of Sound in Air at Low Pressures.—D. E. Caro & L. H. Martin. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 760–768.) Loudspeakers were arranged at the ends of a tube and measurements were made of the time of transit of a pulse between two microphones mounted about 4 m apart in the wall of the tube, using the two loudspeakers alternately. Frequencies of 250 c/s and 1 kc/s were used. The mean velocity at 20°C is found to be 343·40 ± 0·02 m/s, and is independent of pressure over the range 5–760 mm Hg.

534.846.6 **616**

Investigation of the Acoustics of Large Halls using Models.—R. Lamoral & R. Trembasky. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 570–575.) 1-ms pulses of a 30-kc/s signal from an ionophone were transmitted via a tube to a 1/30-scale model. Echoes received on a miniature microphone in the model were recorded by c.r.o.

621.395.61 : 621.375.132 **617**

Note on the Application of Negative Feedback to Electroacoustic Devices.—P. Poincelot. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 576–577.) The improvement of the response curve of an electrodynamic microphone on application of negative feedback [1068 of 1950 (Chavasse & Poincelot)] is mentioned as an illustration of the advantages of this technique.

621.395.623.7 **618**

Power Capacity of Loudspeakers.—P. S. Veneklasen. (*Trans. Inst. Radio Engrs*, Sept./Oct. 1953, Vol. AU-1, No. 5, pp. 5–6.) The power-handling capacity is determined by observing the departure from linearity of the acoustic-output/electric-input curves, using octave bands of thermal noise. This method is under consideration for inclusion in a new I.R.E. standard, and comments are invited by the I.R.E. Electroacoustics Committee.

World Radio History

621.395.625.3 : 534.862 : 534.76 **619**

Stereophony in the Cinema.—J. Moir. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 6–9.) Systems using multiple magnetic sound tracks in conjunction with wide screens are described.

621.395.625.3 : 679.5 **620**

The Manufacture of Magnetic Tapes.—C. P. Fagan. (*Plastics*, Sept. 1953, Vol. 18, No. 194, pp. 323–324.) Materials and processes used in the manufacture of plastic-based tapes are described; advantages of polyester-resin base materials are mentioned.

AERIALS AND TRANSMISSION LINES

621.315.212 : 621.372.2 **621**

Highly Flexible Coaxial Cable with Helical Outer Conductor.—H. Weiss. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 516–526.) Cable sections suitable for replacing rotary joints are studied, the attenuation being of only secondary importance in this case. The amounts of power transmitted internally and externally are calculated separately; the externally transmitted power becomes zero for a helix pitch of 90° (i.e., ordinary coaxial cable). Dielectric and ohmic losses are discussed and the effect of the distribution of the outer conductor is investigated.

621.315.212 : 621.372.8 **622**

The Transverse Electromagnetic Lecher Wave in Coaxial Cable as a Degenerate Waveguide Wave.—H. Kleinwächter. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 467–469.) The transverse Lecher wave, which is a degenerate E_0 wave, is shown to be the only mode without an axial component which can be propagated in a coaxial cable without attenuation.

621.372.2 **623**

An Investigation of the Characteristics of Cylindrical Surface Waves.—H. M. Barlow & A. E. Karbowiak. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 321–328. Discussion, pp. 341–347.) An account is given of an experimental study using a frequency of about 10 kMc/s. For accurate work, the line used was about 4 ft long, short-circuited at both ends by transverse metal plates and excited at resonance, the usual launching horns being dispensed with. Descriptions are given of an axial standing-wave indicator and an instrument for determining the radial field distribution, both designed as far as possible to avoid disturbing the field. Measurements of the decay coefficients of No. 24 s.w.g. Cu wire thickly coated with polythene diverged widely from the values derived from Goubau's approximate theory. On revising the assumptions in the theory, values in agreement with the experimental results were obtained. The surface-wave resonator can also be used for measuring the surface reactance of corrugated surfaces.

621.372.2 **624**

Surface Waves.—H. M. Barlow & A. L. Cullen. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 329–341. Discussion, pp. 341–347.) Unified theory is presented for various forms of surface wave, namely the Zenneck wave, the radial cylindrical surface wave, and the Sommerfeld-Goubau or axial cylindrical surface wave. The significance of the Brewster angle of incidence, for which a wave suffers no reflection, is established. The parallel-plate transmission line is discussed and the transition is demonstrated from the TEM wave supported when the plates are close together to the two separate Zenneck waves when the plates are separated by a sufficient distance. The effect of bends in the line is considered and methods of reducing radiation are explained. Launching processes are surveyed with particular reference to the Brewster-angle approach.

621.372.2 : 538.566 **625**

The Types of Wave which may exist near a Guiding Surface.—J. Brown. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 363–364.) It is shown theoretically that the waves near a guiding surface can be classified as guided surface waves, evanescent fields or radiation fields. The evanescent fields differ from those in a transmission line or waveguide in that all values of attenuation constant are possible.

621.372.2.012.11 **626**

The Circle Diagram for Reflection Coefficient.—E. Thinius. (*Fernmeldetech. Z.*, Oct. 1953, Vol. 6, No. 10, pp. 468–469.) A chart is presented from which it is possible to obtain the curve for reflection coefficient as a function of frequency.

621.372.8 **627**

The Influence of Bends and Ellipticity on the Attenuation and Propagation Characteristics of the H_{01} Circular Waveguide Mode.—G. D. Sims. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 25–33.) Measurements made with a wave analyser, mainly at a wavelength of 3·2 cm, are reported. Jouguet's theory of propagation in a curved waveguide (3786 of 1947) is discussed and a brief account is given of experiments confirming it. The value of 3·4 db/km obtained for the attenuation in a long closed Cu waveguide, using a multiple-reflection technique, is about three times the theoretical figure; the difference is attributed to losses due to ellipticity and surface roughness.

621.372.9 **628**

Reflection of Electromagnetic Waves at Inhomogeneous Boundary Surfaces with a Periodic Structure Perpendicular to the Electric Vector.—R. Müller. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 492–500.) The particular cases considered mathematically include the incidence of an H_{10} wave in a rectangular waveguide on a slit diaphragm, the incidence of a plane e.m. wave on a stack of matching plates, and the incidence of an H_{10} wave on a discontinuous rectangular coupling section.

621.372.8 **629**

X-Band Rotary Joint.—H. J. Riblet & R. L. Williston. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 23–24.) A transition section for operation with high power takes the form of a tapered ridged waveguide; voltage s.w.r. is not greater than 1·02 over an 11% frequency band.

621.396.67 **630**

Some Optical Aspects of Antenna Radiation and Reception.—J. L. Salpeter. (*Philips tech. Commun., Aust.*, 1953, No. 3, pp. 3–10.) Similarities and differences between the e.m. radiations constituting light and those constituting radio waves are outlined; the former are usually noncoherent, the latter coherent. Differences in the design of radiators, reflectors and lenses for light waves and those for radio waves are explained on this basis.

621.396.67 + 621.372.8](083.74) **631**

I.R.E. Standards on Antennas and Waveguides: Definitions of Terms, 1953.—(*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1721–1728.) Standard 53 IRE 2S1.

World Radio History

621.396.676 632

Short Antennas for Mobile Operation.—J. S. Belrose. (*QST*, Sept. 1953, Vol. 37, No. 9, pp. 30–35, 108.) Simple numerical calculations are presented of the radiation resistance, efficiency, effective height, input reactance, etc., of unloaded and loaded vertical aerials near the ground. The results are in good agreement with those determined from field-strength measurements.

621.396.677.3 633

A High-Resolution Aerial System of a New Type.—B. Y. Mills & A. G. Little. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 272–278.) A horizontal aerial system, in the form of crossed arrays consisting of dipoles all of which are parallel to each other, is described. The experimental model, with 120-ft cross arms, operates at 97 Mc/s; the beam width is 8°. Work on a 1°-beam-width system for operation at about 80 Mc/s is in progress. The elementary theory and results of some radio-astronomy measurements are given.

621.396.677.31 634

A Simplified Calculation for Dolph-Tchebycheff Arrays.—G. J. van der Maas. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, p. 1250.) An alternative series is derived which is more suitable for the numerical calculation of the currents in individual elements than that given by Barbiere (1211 of 1952).

621.396.677.71 : 535.42 635

Babinet's Principle and the Slot Antenna.—J. L. Salpeter. (*Philips tech. Commun., Aust.*, 1953, No. 4, pp. 3–15.) Simple theory of the slot aerial is developed from optical diffraction theory. The complementary aspects of dipoles and slot aerials are discussed.

621.396.677.73 636

Calculation of the Gain of Small Horns.—E. H. Braun. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1785–1786.) A simple procedure is given for extending the range of the curves presented by Schelkunoff ('Electromagnetic Waves') to cover horns whose dimensions are small compared with λ.

621.396.677.73 : 621.396.677.8 637

Antennas Fed by Horns.—B. Berkowitz. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1761–1765.) Formulae are derived for the E- and H-plane radiation patterns as functions of illumination taper. The case of a lens or reflector associated with two contiguous horns stacked in either of the principal planes is investigated. By introducing an 'illumination factor', defined in terms of physical dimensions, the following properties are related:—(*a*) loci of half-power beam widths, nulls and side-lobe peaks; (*b*) illumination taper at edge of lens or reflector; (*c*) crossover power; (*d*) spillover power; (*e*) gain referred to the feed horn.

621.396.677.8 : 538.52 : 537.311.5 638

On the Current Induced in a Conducting Ribbon by a Current Filament Parallel to it.—Moullin. (See 704.)

621.396.677.85 639

Artificial Dielectrics having Refractive Indices less than Unity.—J. Brown. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 51–62; Summary, *ibid.*, Part III, Sept. 1953, Vol. 100, No. 67, pp. 319–320.) Two types are considered, the first comprising an array of conducting rods and the second a set of perforated parallel conducting plates. Both are designed for operation with a wave polarized so that its electric field is parallel to the conducting elements. The method of calculating the effective refractive index is indicated. The reflection occurring at the interface between the medium and free space is investigated.

AUTOMATIC COMPUTERS

681.142 640

Programme Design for the C.S.I.R.O. Mark I Computer: Part 1 — Computer Conventions.—T. Pearcey & G. W. Hill. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 316–334.) See also 1050 of 1953 (Beard & Pearcey).

681.142 641

Programme Design for the C.S.I.R.O. Mark I Computer: Part 2 — Programme Techniques.—T. Pearcey & G. W. Hill. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 335–356.) Part 1: 640 above.

681.142 642

Recent Electronic Computers and their Applications.—D. Dainelli & E. Aparo. (*Ricerca sci.*, Sept. 1953, Vol. 23, No. 9, pp. 1528–1549.) Digital computers are described and compared in respect of operating speed and structure.

681.142 643

A Mathematical Basis for an Error Analysis of Differential Analyzers.—K. S. Miller & F. J. Murray. (*J. Math. Phys.*, July/Oct. 1953, Vol. 32, Nos. 2/3, pp. 136–163.)

681.142 644

Analogue Computer for Aircraft Design.—(*Elect. J.*, 18th Sept. 1953, Vol. 151, No. 12, pp. 893–894.) A compact general-purpose instrument designed for economical quantity production.

681.142 : 531.77 645

An Analog-to-Digital Converter.—A. D. Scarbrough. (*Trans. Inst. Radio Engrs*, Sept. 1953, Vol. EC-2, No. 3, pp. 5–7.) A device for giving the angular position of a slowly rotating shaft as a binary number uses a mechanical counter which goes from zero to full capacity during one revolution of the shaft. The counter may comprise a series of cams associated with switches. On application of a reading pulse, the number registered by the counter is made available as a pattern of pulses, the arrangement being suitable as an input device for a digital computer.

681.142 : 621-526 646

Servo Systems for performing Mathematical Operations.—E. Wall. (*Product Engng*, Sept. 1953, Vol. 24, No. 9, pp. 134–140.) By combining servomechanisms with computing systems involving mechanical or electrical analogies, loading effects, which tend to introduce inaccuracies, are eliminated. An outline is given of procedures for addition and subtraction, determination of powers and roots, solution of triangles, and integration.

681.142 : 621.385 647

The Univac Tube Program.—T. D. Hinkelman & M. H. Kraus. (*Trans. Inst. Radio Engrs*, Sept. 1953, Vol. EC-2, No. 3, pp. 8–12.) Account of an integrated programme, starting with the design and initial selection, for ensuring reliable performance of valves in a large-scale computer.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.011.21.012.1 648

Rapid Parallel-Z Calculations.—L. Storch. (*Tele-Tech*, Aug. 1953, Vol. 12, No. 8, pp. 91–93, 193.) Use of a special graph paper with both polar and rectangular coordinates facilitates the calculation. A ruler is the only instrument required in this graphical method.

World Radio History

621.3.012 : [621.318.42 + 621.372.4 649

The Calculation of Nonlinear Networks by means of Composite-Straight-Line Characteristics.—A. Hochrainer. (*Elektrotech. u. Maschinenb.*, 1st Sept. 1953, Vol. 70, No. 17, pp. 376–386.) Many circuit problems are simplified by substituting for an actual curved characteristic an approximation built up of rectilinear sections. Use of the method is illustrated by studying the characteristics of iron-cored coils with and without hysteresis, and with and without magnetic bias, and by analysing the free oscillations of a circuit including an iron-cored coil. Emphasis is laid on the point that the actual shape of the nonlinear characteristic is less significant than the simple fact of its deviation from linearity.

621.3.018.78 650

Harmonic and Intermodulation Distortion in "Power Law" Devices.—D. G. Lampard. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 3–7.) Explicit expressions are derived for the intermodulation components produced when two sinusoidal voltages are applied simultaneously to a device, such as a diode, whose transfer characteristic can be represented by a simple power-law formula. Results of practical importance in intermodulation-distortion testing are presented graphically.

621.315.332 + 621.316.8 + 621.319.4 651

Components for Severe Conditions of Use.—L. Podolsky. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 510–515.) A discussion of the factors to be considered in the design of capacitors and resistors for use under extreme temperature and humidity conditions, particularly when the components are required to be as small as possible. The use of ceramic-covered wire for the windings of transformers, etc., to withstand high temperatures is mentioned.

621.316.726.029.6 : 621.376.3 652

Frequency Discrimination and Stabilization of Square-Wave-Modulated Microwave Transmissions.—C. H. M. Turner. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 381–383.) The method described is a modification of that due to Aurell (M.I.T. Technical Report No. 30). The frequency of the oscillations from a reflex klystron is compared with the resonance frequency of a high-Q cavity, and a correction voltage depending on the frequency difference is fed back to the klystron reflector electrode via the modulator, where it is combined with the square-wave modulation voltage. The method of alignment of the microwave circuits is discussed in detail, and the effect of misalignment on the discriminator characteristics is shown.

621.316.86 : 537.312.6 653

Properties and Applications of Thermistors.—J. Bleuze. (*Onde élect.*, Aug./Sept. & Oct. 1953, Vol. 33, Nos. 317/318 & 319, pp. 497–509 & 578–590.)

621.316.89.029.5 654

Theory of the Boella Effect.—U. Tiberio. (*Alta Frequenza*, June/Aug. 1953, Vol. 22, Nos. 3/4, pp. 184–187.) A discussion of the mechanism causing the drop in the resistance of composition resistors at h.f. (1934 Abstracts, p. 454). A similar variation of resistance with frequency has been observed in electrolytic solutions (Debye-Falkenhagen effect). Comparative measurements were made on 30-kΩ resistors of three different types, namely (*a*) ceramic rod with helical carbon film ('low-resistance type'), (*b*) carbon/resin composition in ceramic case ('high-resistance type'), and (*c*) capillary tube containing a solution of $CuSO_4$ in water (electrolyte type). The Boella effect was most marked in case (*b*). Variation of resistance with electric field strength is also observed. The explanation given is alternative to that of Howe (3226 of 1935).

621.318.4.015.4 655

Natural Frequencies of Coils and Windings.—P. A. Abetti & F. J. Maginniss. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, p. 781.) Digest only. Calculations for an equivalent circuit consisting of reactors only were made using (*a*) punched-card equipment, (*b*) an a.c.-network analyser. The effect of neglecting the mutual inductance between elements, partly or completely, is shown graphically. Very close agreement with measured natural frequencies was obtained.

621.318.423.011 656

Air-Core Coil Design for Crossover Networks.—A. Meyer. (*Trans. Inst. Radio Engrs*, Sept./Oct. 1953, Vol. AU-1, No. 5, pp. 9–11.) Simple analysis is given for determining the correct wire gauge and optimum coil dimensions for specified values of Q and L. Results are shown in charts, and numerical examples illustrate their use.

621.318.435.3.025.3 : 621.375.3 657

Three-Phase Transductor Circuits for Magnetic Amplifiers.—A. G. Milnes. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 1–2.) Discussion on 949 of 1953.

621.318.57 : 621.314.7 658

Transistors: Theory and Application: Part 10—Switching Circuits using the Transistor.—A. Coblenz & H. L. Owens. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 186–191.) Counter circuits, relaxation oscillators, etc., using point-contact transistors are described. Part 9: 341 of February.

621.318.57 : 621.314.7 659

The Phase-Bistable Transistor Circuit.—R. H. Baker, I. L. Lebow, R. H. Rediker & I. S. Reed. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, p. 1760.) Corrections to paper noted in 3515 of 1953.

621.318.572 : 621.385.832 660

The E1T Decade Counter Tube.—(*Electronic Applic. Bull.*, May 1953, Vol. 14, No. 5, pp. 71, 76.) Corrections and addendum to paper noted in 603 of February.

621.372 661

A Note on the Network Postulates.—M. G. Arsove. (*J. Math. Phys.*, July/Oct. 1953, Vol. 32, Nos. 2/3, pp. 203–206.) Kirchhoff's law, that the sum of the potential differences about any closed path of branches is zero, is replaced by a version making no explicit references to paths of branches. The resulting law can be interpreted geometrically in terms of orthogonal subspaces of a certain vector space. The network definition given is readily shown to be invariant under changes of basis. The equivalence between the new definition and the classical one is established.

621.372 662

The Return-Difference Matrix in Linear Networks.—L. Tasny-Tschiassny. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 39–46.) Bode's concept of the 'return difference' is generalized by replacing the quantities concerned by matrices. A formula for the 'fractionated gain' is derived which is a generalization of Thévenin's theorem. Formulae are also derived for the stability of a circuit, for the variation of its output as a result of imperfections of the circuit elements, and for the input and output impedance. The method is particularly useful for analysing multiple-loop feedback circuits.

World Radio History

621.372 663

A Graphical Contribution to the Analysis and Synthesis of Electrical Networks.—O. P. D. Cutteridge. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 83–90. Digest, *ibid.*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 377–379.) "The contribution of the poles and zeros of a network function to the steady-state characteristics at real frequencies is considered by means of vectors, and the connection between attenuation and phase is thereby accentuated. Bode's relation between attenuation and phase in minimum-phase networks is derived by considering the contributions from individual singularities and using a known definite integral in a real variable. Details are derived for the construction of a series of templates, useful for finding pole-zero positions which yield certain attenuation, phase and delay characteristics, and vice versa." The method is illustrated by examples including the estimation of the phase and delay characteristics corresponding to the given attenuation characteristic of a minimum-phase wide-band amplifier.

621.372 664

The Relations between Circuit Pass Band and Signal-Build-up Time.—P. Poincelot. (*C. R. Acad. Sci., Paris*, 16th Nov. 1953, Vol. 237, No. 20, pp. 1217–1218.) Two pass-band criteria are discussed, namely (*a*) the bandwidth between the 3-db points and (*b*) the bandwidth defined in terms of spectral distribution of energy. It is shown that these are not uniquely related and that it is not possible to determine the time constant of a circuit solely from a knowledge of its bandwidth.

621.372 : 512.831 665

Voltage-Reference Node.—J. Shekel. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 6–10.) Description of a general method of analysing linear networks by nodal analysis without specifying the node to which all voltages are referred; the network can be represented by an indefinite admittance matrix, which can be brought to a definite form by omitting the row and column corresponding to a specified reference node. The method is useful for dealing with valve circuits with earthed-grid or earthed-anode stages or with no earthed electrodes.

621.372.2 : 534.321.9 666

Fused-Quartz Ultrasonic Delay-Line Memory.—D. A. Spaeth, T. F. Rogers & S. J. Johnson. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 151–153.) The digit-storage unit described is of the type comprising a slab of fused quartz providing a folded transmission path. Methods are indicated for eliminating spreading of the ultrasonic beam and mode conversion at the reflecting surfaces, thus reducing the intensity of spurious signals. An ultrasonic frequency of 40 Mc/s is used, and pulses with a dynamic range of 40 db can be stored at rates $>5 \times 10^6$/sec.

621.372.412 667

Some Notes on the Properties and Manufacture of Piezoelectric Quartz Crystals.—H. L. Downing. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1953, Vol. 14, No. 10, pp. 241–248.) The frequency stability, temperature coefficient and activity of quartz resonators are discussed, and the relation between these properties and the oscillation frequency of a circuit including the crystal is examined. The performance of some typical units is shown graphically.

621.372.413 668

Double Compensated Tunable Cavity.—T. S. Saad. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 25–28.) Two-frequency temperature compensation of hermetically sealed cavities filled with dry inert gas is described. A typical performance curve is shown.

621.372.5 + 621.375.23 669

Differentiating Circuits.—R. L. Ford. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 519–521.) Passive-network and feedback-amplifier types of differentiator are discussed, and the performances of two variants of the latter type are compared.

621.372.5 670

Determination of the Input Impedance of Linear Quadripoles by a Graphical Method.—M. Klobe. (*Nachr-Tech.*, Sept. 1953, Vol. 3, No. 9, pp. 421–424.) The data required are the characteristic impedance, the load or terminal impedance and the propagation constant of the quadripole. Two examples are worked out.

621.372.5 671

Build-Up Phenomena in Minimum-Phase Networks.—H. Holzwarth. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 473–477.) Wheeler's paired-echo method (3642 of 1939) is used to evaluate the network response to a single pulse and to a step voltage. The method is fundamentally a simplified application of the Fourier integral and is particularly useful for evaluating the distortion with a minimum of computation.

621.372.5 672

The Equivalent *Q* of RC Networks.—L. A. Wyatt: D. A. H. Brown: D. W. R. Wheeler. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, p. 534.) Further comments on 2919 of 1953 (Brown).

621.372.52 : 621.373.421 673

Theory of Twin-T RC Networks and their Application to Oscillators.—A. P. Bolle. (*J. Brit. Instn Radio Engrs*, Dec. 1953, Vol. 13, No. 12, pp. 571–587.) The conditions are established which the circuit elements must satisfy (*a*) for the network to produce infinite attenuation at one frequency, ω_0, and (*b*) for the output to be either in phase or in phase opposition with the input at ω_0 on varying two elements in a particular manner. The slope of the phase/frequency characteristic at $\omega = \omega_0$ is compared with that of a resonant *LC* circuit. One-valve oscillators incorporating such networks are discussed, with particular attention to distortion and stability. Results of measurements on an oscillator are compared with values calculated from theory.

621.372.542.22 : 621.372.412 674

Design Procedure for Crystal Lattice Filters.—W. C. Vergara. (*Tele-Tech*, Sept. 1953, Vol. 12, No. 9, pp. 86–87.) The technique of filter design is described and formulae for the electrical and mechanical constants of −18·5° X-cut quartz crystals are given. A bridge network of two divided-electrode crystals operating at 135 kc/s has an image impedance of 425 kΩ.

621.372.542.4.029.3 675

The Basic Design of Constant-Resistance Crossovers.—N. H. Crowhurst. (*Audio Engng*, Oct. 1953, Vol. 37, No. 10, pp. 21–22..110.) A simple mathematical analysis of the attenuation and phase characteristics for constant-resistance filters consisting of up to four elements. The frequency response is shown graphically.

621.372.543.2.029.42 676

A Band-Pass Filter for Low Frequencies.—A. H. Silcocks: G. W. Morris & P. G. M. Dawe. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 534–535.) Critical comment on 3237 of 1953 and authors' reply.

621.372.543.2.029.63 677

Duplexing Filter Design at 2000 Mc/s.—D. R. Crosby. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 31–38.) The cavity-resonator-type filters

World Radio History

described are used in commercial communication equipment with transmitter and receiver operating with a frequency separation of 40 Mc/s; both receiving and transmitting filters have a bandwidth of 20 Mc/s.

621.372.56.029.6 **678**

A Comparison of the Properties of Certain Materials used in Low-Power Microwave Attenuators.—F. A. Benson & R. M. Pearson. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 502–505.) Results of measurements on Morganite, antistatic gutta-percha and carbon-loaded bakelite indicate that, if suitably sealed to prevent ingress of moisture, Morganite is the best from the point of view of stability.

621.372.57 : 621.3.018.75 **679**

D.C. Restoring of Variable-Width Rectangular Pulses.—J. van Bladel. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 524–525.) The well-known diode d.c. restoring circuit is discussed; the effect of deviations of source impedance, diode forward resistance and coupling capacitance from their 'ideal' values is investigated. The analysis is illustrated by a practical example.

621.372.57 : 621.385 **680**

Starvation Circuits and their Limitations.—P. J. Erdle. (*Sylvania Technologist*, Oct. 1953, Vol. 6, No. 4, pp. 85–88.) The under-running of valves is deprecated on technical grounds. The valves so operated generally tend to be unstable with variations in the supply voltage and with age.

621.373.4 : 621.316.726 **681**

A Controlled-Frequency Oscillator with Frequency 'Memory'.—J. van Bladel. (*J. sci. Instrum.*, Sept. 1953, Vol. 30, No. 9, pp. 299–301.) An arrangement is described in which a phase-comparison a.f.c. system is used to keep a first oscillator in tune with a second (pilot) oscillator. At a given instant the control loop is broken; thereafter the first oscillator continues to operate at the frequency at the cut-off instant, and subsequent frequency variations of the pilot oscillator are determined from measurements of the phase difference between the two oscillators. A practical circuit which holds frequencies in a band centered on 50 c/s is described.

621.373.4 : 621.385.3 **682**

Oscillator Characteristic Equation.—V. L. Talekar. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 3–6.) The equation for an oscillator circuit using a triode is developed in a form involving the differential coefficients of the dynamic resistance of the triode. Measurements on a Hartley oscillator are reported which are in good agreement with the theoretical results over most of the oscillation characteristic. Particular features of the oscillation characteristics are discussed, and the constants of the triode and the tank circuit are deduced from them.

621.373.4 : 621.396.822 **683**

Effect of Valve Noise on Oscillators.—A. Blaquière. (*C. R. Acad. Sci., Paris*, 23rd Nov. 1953, Vol. 237, No. 21, pp. 1316–1318.) The magnitudes of the valve shot effect and circuit thermal noise in oscillators are compared. When the oscillatory circuit is connected to the grid, the valve noise is relatively negligible; when the oscillatory circuit is connected to the anode, the valve noise preponderates.

621.373.42.029.63 **684**

Tuned Circuit Oscillators at U.H.F.—W. H. Elkin. (*Marconi Instrumentation*, Sept. 1953, Vol. 4, No. 3, pp. 50–54.) The design of a disk-seal-triode oscillator for frequencies up to 1 kMc/s is discussed. The causes of spurious resonance, and their elimination, are considered.

621.373.421 **685**

High-Frequency Resistance-Capacitance Oscillators.—G. W. Holbrook. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 509–511.) The relative merits of shunt-capacitance and shunt-resistance oscillators are discussed. The conditions of oscillation are analysed and the upper frequency limits are examined.

621.373.422/.43 **686**

Sinusoidal and Relaxation Oscillations sustained by Nonlinear Reactances.—R. S. Mackay. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1163–1167.) Descriptions are given of various combinations of nonlinear components (e.g., a saturating choke) with linear components (e.g., a capacitor) whereby negative-resistance characteristics can be obtained either of the type in which current is a single-valued function of voltage, or of the type in which voltage is a single-valued function of current. Practical applications are discussed.

621.373.52.029.4 **687**

A Transistor M.C.W. Adapter.—H. V. Braun. (*QST*, Sept. 1953, Vol. 37, No. 9, p. 51.) A miniature keyed a.f. *RC* oscillator is described.

621.375.2.024 : 621.314.58 **688**

Magnetic-Converter D.C. Amplifier.—W. A. Rote. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 170–173.) The d.c. amplifier described comprises a magnetic second-harmonic converter followed by an a.c. amplifier. D.c. signals with power as low as 2×10^{-15}W can be amplified.

621.375.2.029.4.012.3 **689**

Audio Nomographs.—J. F. Sodaro. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 200, 202.) Charts are presented for designing a pentode a.f. amplifier to have desired gain and bandwidth. The method involves the use of separate equivalent circuits for the upper, middle and lower parts of the frequency band.

621.375.232.4.029.63 **690**

Disk-Seal-Triode Amplifiers for Decimetre-Wavelength Radio Links.—A. Egger & G. Pusch. (*Fernmeldetech. Z.*, Oct. 1953, Vol. 6, No. 10, pp. 486–490.) Amplifiers for increasing the transmitter output power and receiver sensitivity in existing links are considered. Grounded-grid circuits are used; simple formulae are derived for gain and bandwidth, giving values in good agreement with experimental results obtained with Type-EC55 and Type-2C39A valves.

621.375.3 **691**

Magnetic Amplifier Circuits and Applications.—R. A. Ramey. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, pp. 791–795.) A chronological survey.

621.375.421 : 621.314.7 **692**

The Surface-Barrier Transistor: Part 3 — Circuit Applications of Surface-Barrier Transistors.—J. B. Angell & F. P. Keiper, Jr. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1709–1712.) The operating characteristics of the surface-barrier transistor are discussed and two amplifier circuits are described, namely (*a*) a wide-band low-pass amplifier, and (*b*) a band-pass amplifier for a centre frequency of 30 Mc/s. This type of transistor combines the ability to operate at v.h.f. with the low power consumption of the junction type. Part 2 : 896 below.

World Radio History

631.396.6.002.2 **693**

Mechanized Production of Electronic Equipment.—R. L. Henry & C. C. Rayburn. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 160–164.) An illustrated account is given of production methods developed at the National Bureau of Standards, based on modular design. A steatite wafer $\frac{3}{8}$ in. × $\frac{3}{8}$ in. × $\frac{1}{16}$ in. is used as a basic unit on which components are printed or mounted over printed wiring. Six of these wafers are automatically stacked and connected to form a plug-in unit. Automatic silver-painting, tuning, dip-soldering and testing machines are used. For other accounts see *Tech. News Bull. nat. Bur. Stand.*, Nov. 1953, Vol. 37, No. 11, pp. 161–170 and *Tele-Tech*, Nov. 1953, Vol. 12, No. 11, pp. 70–72..136.

621.396.6.002.2 **694**

Automatic Assembly of Electronic Equipment.—L. K. Lee & C. Brunetti. (*Elect. Mfg*, July 1953, Vol. 52, No. 1, pp. 97–109..308.) Description of a complete production line for a radar chassis; attaching machines fix components on a printed-circuit base plate.

621.396.6.002.2 : 621.357 : 621.315 **695**

A Flexible Plated Circuit.—E. R. Bowerman & R. F. Walton. (*Radio & Telev. News, Radio-Electronic Engng Section*, Sept. 1953, Vol. 50, No. 3, pp. 12–13.) The 'wiring', initially formed as a 0·001–0·003-in. thick, Cu electrodeposit on a stainless steel plate, is stripped off on a cloth-backed adhesive tape. The complete manufacturing process is described.

GENERAL PHYSICS

537.52 **696**

The Ignition Mechanism of an Electric Gas Discharge in a Transverse Magnetic Field at Pressures of 10^{-1}–10^{-8} Torr.—R. Haefer. (*Acta phys. austriaca*, July 1953, Vol. 7, No. 3, pp. 251–277.) Continuation of work noted in 112 of January. A nonuniform field is obtained by making the radius of the outer cylinder much greater than that of the inner. The ignition characteristic (ignition-voltage magnetic-induction × electrode separation) obtained by calculation is compared with measurements in Ar; the agreement is good. The ionization coefficient is independent of pressure and the electron replacement coefficient is proportional to pressure. With high voltages and low magnetic fields the electrons are produced mainly by ionic bombardment of the outer cylinder and by ion collisions in the gas; with low voltages and high magnetic fields the electrons are produced mainly by ionic bombardment of the end surfaces. A formula relating the electron replacement coefficient to the ratio between the mean free path and the parameter of the cycloidal electron trajectory gives results in good agreement with those derived from the observed ignition characteristics.

537.52 + 523.72] : 621.383 **697**

Study of High-Frequency Fluctuations from Light Sources using Phototubes and Tuned Radio-Frequency Amplifiers.—K. Landecker & B. J. Robinson. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 737–742.) Observations have been made at frequencies up to 95 Mc/s, using two different amplifiers for the ranges below and above 25 Mc/s; the methods of connecting the photocell (R.C.A. Type 919) to the amplifiers are described. The spatial distribution of some types of oscillation along the axis of vapour discharges was investigated. Attempts to observe fluctuations of light from the sun have been made only during 'quiet' periods and have so far yielded negative results.

537.521.7 **698**

Calculation of the Behaviour of Sparks with Resistance and Self-Inductance in the Circuit.—W. Weizel. (*Z. Phys.*, 25th Sept. 1953, Vol. 135, No. 5, pp. 639–657.)

537.521.7 : 681.142 **699**

Analogue-Computer Solution of the Differential Equation for a Spark Gap.—A. Walther & K. J. Lesemann. (*Z. Phys.*, 25th Sept. 1953, Vol. 135, No. 5, pp. 658–664.) The differential equation derived by Weizel (698 above) is easily solved by means of the I.P.M.-Ott integrator.

537.533.8 **700**

Neutralization of Ions and Ionization of Atoms near Metal Surfaces.—L. J. Varnerin, Jr. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 859–863.) When an ion or an atom approaches a metal surface, neutralization or ionization processes are often possible. The Franck-Condon principle is applied in the determination of the probability of electron transfers. Such transfers are limited to definite ranges of separation from the surface. Most secondary-electron emission is due to an Auger-type process, the contribution due to de-excitation of metastable atoms being very small.

537.56 **701**

Ionization Phenomena in Gases.—A. von Engel & G. Francis. (*Nature, Lond.*, 31st Oct. 1953, Vol. 172, No. 4383, pp. 798–799.) A brief summary of papers presented at the conference held in Oxford in July 1953. The subjects discussed included the spark, arc, glow and h.f. discharges, G-M counters and fundamental processes.

537.562 **702**

Theory of Ionized Media with Distant Boundaries.—M. Hoyaux. (*Rev. gén. Élect.*, Sept. 1953, Vol. 62, No. 9, pp. 421–438.) Continuation of work noted in 381 of 1952. The theory is developed for a configuration in which the electrodes are relatively close while the boundaries are relatively distant. Experimental results confirm the theory. The solution of the differential equations involved, and summarized theory of the potential distribution in the mercury-vapour-rectifier arc are given in appendices.

537.564 **703**

Ionization of Gas by Electrons.—J. K. Knipp, T. Eguchi, M. Ohta & S. Nagata. (*Progr. theor. Phys., Osaka*, July 1953, Vol. 10, No. 1, pp. 24–30.) A statistical analysis is made of the ionization produced by an electron when it is absorbed in hydrogen. Linear integral equations are obtained for the average number and the mean-square fluctuations of the ion pairs. These are evaluated approximately for high values of incident energy.

538.52 : 537.311.5 : 621.396.677.8 **704**

On the Current Induced in a Conducting Ribbon by a Current Filament Parallel to it.—E. B. Moullin. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 379–381.) Digest only. The discussion presented makes use of results obtained previously [2723 of 1952 (Moullin & Phillips)] and constitutes one stage in the determination of the diffraction pattern obtained with a system of aerials in the presence of a metal reflector of arbitrary size and shape.

538.56.029.66 : 061.3 **705**

Microwave Optics.—E. Wolf. (*Nature, Lond.*, 3rd Oct. 1953, Vol. 172, No. 4379, pp. 615–616.) Account of a symposium held at McGill University, Montreal, in June 1953.

World Radio History

538.566 : 535.42/.43 706

Solution of Electromagnetic Scattering Problems as Power Series in the Ratio (Dimension of Scatterer)/Wavelength.—A. F. Stevenson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1134–1142.) The calculation of the successive terms in the series expressing the scattered field requires only the solution of standard problems in potential theory, together with the evaluation of certain potential integrals. The series can be calculated as far as desired if Laplace's equation can be solved, but the calculation is increasingly complex for successive terms. The special case of scattering by a perfect conductor is also considered and its relation to the problem of diffraction by an aperture in a conducting screen is indicated. Expressions for the distant field are derived.

538.566 : 535.42/.43 707

Electromagnetic Scattering by an Ellipsoid in the Third Approximation.—A. F. Stevenson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1143–1151.) The method described in 706 above is used to evaluate the first three terms of the power series in k ($= 2\pi\lambda$), viz. those in k^2, k^3 and k^4; the term in k^3 vanishes because of the symmetry of the scattering body. The result is expressed as the sum of two elliptic integrals, which are functions of the three principal axes of the ellipsoid. The special cases of the spheroid, perfectly conducting ellipsoid, perfectly conducting disk and of diffraction by an elliptical or circular hole in a perfectly conducting screen are considered.

538.566 : 535.42 708

The Vector Wave Function Solution of the Diffraction of Electromagnetic Waves by Circular Disks and Apertures: Part 1 — Oblate Spheroidal Vector Wave Functions. Part 2 — The Diffraction Problems.—C. Flammer. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1218–1231.) The vector wave functions considered are the solenoidal solutions of the vector Helmholtz equation. Oblate spheroidal vector wave functions are defined and the expansions for plane polarized waves in terms of them are obtained. A unique solution is obtained for the diffraction by an infinitely thin, perfectly conducting circular disk and by a circular aperture in a plane conducting screen. Two separate groups of these functions are combined to fulfil the condition $E_\phi = 0$ at the rims of the aperture and disk, using the spheroidal coordinate system η, ξ, ϕ.

538.566 : 535.42 709

Diffraction of Electromagnetic Waves by an Aperture in a Large Screen.—G. Bekefi. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1123–1130.) The approximate solution of the three-dimensional diffraction problem is obtained by using a single component of the Hertz vector. The results are applied to the calculation of the field in the plane of a circular aperture which is large compared with the wavelength. Experiments confirm some of the theoretical results.

538.566 : 535.42 710

Diffraction of Electromagnetic Waves by Two Parallel Half-Planes.—B. N. Harden. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 348–350.) The field of a plane wave diffracted by the edges of two parallel conducting sheets has been measured close to the diffracting edges for various spacings between the sheets. Experimental results for a spacing of one wavelength are compared with values derived from theory presented by Clemmow (1620 of 1951); the agreement is satisfactory.

537.5 711

Electronic and Ionic Impact Phenomena. [Book Review]—H. S. W. Massey & E. H. S. Burhop. Publishers: Clarendon Press, Oxford, 1952, 699 pp., 70s. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 851–853.) " . . . this work is likely to be the standard reference book on the subject for some time to come."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.5 : 621.396.969.3 712

The Radio Echo from the Head of Meteor Trails.—I. C. Browne & T. R. Kaiser. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 1–4.) Calculations based on diffraction theory give values for the intensity of head echoes in agreement with observation, and also indicate that the ratio between the intensity of the head echo and that of a specularly reflected body echo should be proportional to the radio wavelength and inversely proportional to the difference in range between these echoes. Other anomalous meteor echoes may arise from discontinuities associated with visual flares.

523.53 : 621.396.96 713

Radar Determination of the Height of Disappearance of Meteor Trails of Known Radiant.—P. Volmer. (*C. R. Acad. Sci., Paris*, 2nd Nov. 1953, Vol. 237, No. 18, pp. 1065–1067.) Observations were made during the period 11th–13th August 1952 at Meudon, using radar equipment operating on a wavelength of 4 m with a peak power of about 100 kW. Curves representing the time variation of the distance of the theoretically nearest reflection point for various values of the height h at which the trails disappear are shown together with observed nearest reflection points. From the comparison it is deduced that the mean value of h is about 85 km.

[523.72 + 523.85] : 621.396.822 714

A Symposium on Radio-Astronomy at Jodrell Bank.—R. H. Brown. (*Observatory*, Oct. 1953, Vol. 73, No. 876, pp. 185–198.) Account of the proceedings at the symposium held in July 1953.

523.72 : 621.396.822 715

The Distribution of Radio Brightness over the Solar Disk at a Wavelength of 21 Centimetres: Part 2 — The Quiet Sun — One-Dimensional Observations.—W. N. Christiansen & J. A. Warburton. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 262–271.) Assuming the distribution over the solar disk to be circularly symmetrical at this wavelength, the derived radial brightness distribution shows marked limb-brightening. The observed distribution of brightness is in fair agreement with the calculations made from solar models involving a 10^4°K chromosphere and 0·3–3·0 × 10^6°K corona, provided that the coronal densities lie between 0·5 and 1·0 times the values usually quoted. Conclusive evidence of a quiet-level r.f. emission was obtained. Part 1: 3209 of 1953.

523.72 : 621.396.822 : 621.396.621 716

Two U.H.F. Radiometers (160 Mc/s and 9.350 kMc/s) and Some Radio-Astronomy Applications.—J. Arsac, E. J. Blum, J. H. Lestel & J. L. Steinberg. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 527–532.) Details are given of improved radio-noise receiving equipment used for continuing the experiments previously reported [3402 of 1953 (Steinberg)]; a power-supply unit stable to within 1 part in 10^4 for mains variations of ± 5%, a parabolic-reflector aerial for 9·35 kMc/s, and a dipole aerial array for 160 Mc/s are described. Measurements of the distribution of r.f. brightness over the sun are reported; these include observations made during the solar eclipses of 1951 and 1952.

World Radio History

523.746 717

Progressive Variation of the Shape of the Sunspot Curves.—A. Kiral. (*Naturwissenschaften*, Sept. 1953, Vol. 40, No. 18, pp. 477–478.) Statistical analysis of the sunspot numbers for the 30 eleven-year cycles since 1610 indicates that the asymmetry of the curves is increasing, thus giving support to Gleissberg's theory that there is another cycle with a period of the order of thousands of years.

535.325 : 551.510.52 718

Measurement of Variations in Atmospheric Refractive Index with an Airborne Microwave Refractometer.—H. E. Bussey & G. Birnbaum. (*J. Res. nat. Bur. Stand.*, Oct. 1953, Vol. 51, No. 4, pp. 171–178.) The cavity-resonator refractometer described is essentially the same as that used for previous measurements [2176 of 1951 (Birnbaum)]. Observations were made at heights up to 10 000 ft; examples of strip records obtained are reproduced. The variations were negligible for distances <5 m. Large increases of refractive index were observed on entering cumulus clouds, and intense fluctuations were noted within the clouds.

538.71 719

Airborne Magnetometer for determining All Magnetic Components.—E. O. Schonstedt & H. R. Irons. (*Trans. Amer. geophys. Union*, June 1953, Vol. 34, No. 3, pp. 363–378.) Description of the airborne vector magnetometer Type-1A, an enlarged and modified form of the instrument previously described by Felch et al. (220 of 1948).

550.38 : 551.510.535 : 621.396.11 720

Measurements of the Terrestrial Magnetic Field in the E Layer.—M. Cutolo. (*Nature, Lond.*, 24th Oct. 1953, Vol. 172, No. 4382, pp. 774–775.) Two methods are outlined, both based on determination of the gyro-frequency, which is related by a simple formula to the intensity H of the geomagnetic field in the lower part of the E layer. The first method is based on the double-hump resonance curve (2617 of 1950) and the second is based on the self-demodulation of radio waves at carrier frequencies near gyrofrequency (1758 of 1951). A table is given of values of H determined by these methods in Italy.

550.384 721

A Universal Time Component in Geomagnetic Disturbance.—R. P. W. Lewis & D. H. McIntosh. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 78–80.) Evidence of a universal time component in the diurnal variation of the geomagnetic disturbance is obtained from an analysis of *K*-index figures.

550.384 : 621.396.822.029.42 722

Low-Frequency Noise in the Range 0·5–20 c/s.—J. Aarons & M. Henissart. (*Nature, Lond.*, 10th Oct. 1953, Vol. 172, No. 4380, pp. 682–683.) Continuation of previously noted investigations [1628 of 1948 (Menzel & Salisbury) and 3408 of 1948 (Willis)] of the correlation between l.f. e.m. fluctuations and geomagnetic and solar phenomena. A pickup loop with an effective area of 257 m² was used with an amplifier having a gain of 160 db and a recorder with chart speed of 1 mm/s. An operating site with low-noise characteristics was chosen. Evidence was obtained of frequent storms in the noise-frequency range studied. A diurnal variation similar to that of the Cheltenham *K* indices was observed. Analysis indicates significant correlation between the l.f. noise and the 200-Mc/s solar noise observed 29 days earlier.

551.510.53 : 546.214 723

Daily Variation of Amount of Ozone in the Atmosphere.—K. R. Ramanathan & B. V. R. Murthy. (*Nature, Lond.*, 3rd Oct. 1953, Vol. 172, No. 4379, pp. 633–634.) Observations made at Mount Abu and Ahmedabad from Nov. 1952 to April 1953 showed a substantial increase of ozone during night hours, with rapid change-over from day to night values after sunset.

551.510.535 724

An Interpretation of Vertical-Incidence Equivalent-Height versus Time Recordings on 150 kc/s.—R. Lindquist. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 10–27.) The results of observations made in Pennsylvania, U.S.A., between January 1950 and April 1952 are shown graphically and discussed. One form of echo regularly observed during magnetically disturbed nights is due to one type of sporadic-E stratum. Recorded group and phase heights are compared and the differences compared with those predicted from theory. Results are also given of a preliminary investigation of the effects of solar flares.

551.510.535 725

Investigation of Travelling Disturbances in the Ionosphere by Continuous-Wave Radio.—Y. V. Somayajulu: B. R. Rao & E. B. Rao. (*Nature, Lond.*, 31st Oct. 1953, Vol. 172, No. 4383, pp. 818–820.) Continuous records of the signal intensity of c.w. transmissions over a 640-km path at 9·59 Mc/s and 4·92 Mc/s indicate an F-layer-disturbance velocity of 200–400 m/s. Transmission modes up to $2 \times F$ and $5 \times F$, respectively, were observed. Simultaneous signal-intensity records of two in-line transmitters 240 km apart, operating at $\sim$ 7·5 Mc/s, showed a constant 8·5-min interval between the corresponding maxima, indicating a disturbance velocity of $\sim$ 230 m/s.

551.510.535 726

The Effect of Soft X-rays from the Solar Corona on the Formation of the Normal Ionospheric E layer.—G. Elwert. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 68–77. In German.) A calculation has been made previously of the soft X-rays from the solar corona (*Z. Naturf.*, 1952, Vol. 7a, No. 2, pp. 202–204). The results are used to determine the height at which the radiation is absorbed and the number of electrons present at this height under equilibrium conditions. The results agree well with observations of the normal E layer.

551.510.535 727

The Structure of the F Region of the Ionosphere.—A. A. Weiss. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 291–303.) The effects of temperature cycles, of a decay coefficient which is nonuniform with height, and of vertical tidal drifts are considered. The diurnal and seasonal height variations of the F_2 region are explained qualitatively by postulating, in addition to the vertical tides acting on an isothermal Chapman region, a diurnal temperature cycle. This requires a decay coefficient which does not change rapidly with height. On an alternative hypothesis involving discontinuities in the height gradient of the decay coefficient, tidal drifts are still necessary, but a diurnal temperature cycle is not of major importance.

551.510.535 728

World-wide Diurnal Variations in the F_2 Region.—C. W. Allen. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 53–67.) The chief characteristics of the f_0F_2 variations are described in terms of (*a*) the sunspot-minimum anomaly, (*b*) the sunrise anomaly and (*c*) the diurnal-range anomaly. These anomalies are evaluated quantitatively and extracted from the observations to determine the normal curves. The world distribution of these anomalies is studied and explanations are suggested. Variations of $h'F_2$ do not appear to be related either to the sunspot cycle or to the f_0F_2 variations.

World Radio History

551.510.535 729

The Electron Content of the F_2 Layer above Singapore.—B. W. Osborne. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 82–84.) A comparison of the estimated total ionization present in a unit column below the level of maximum ionization density of the F_2 layer in 1949 and in 1952.

551.510.535 : 550.386 730

Geomagnetic and Ionospheric Relationships.—R. P. W. Lewis & D. H. McIntosh. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 44–52.) The effect of a magnetic 'disturbance' on various geomagnetic and ionospheric parameters is investigated by choosing days on which the K_p sum is markedly different from that of the adjacent days. Most of the parameters show a peak or trough corresponding to that of the disturbance, following it with a delay of 0–18 hours. Particular attention is called to some peculiar seasonal effects, to features of the sporadic E layer at Slough and the vertical movement of the F_2 layer at Huancayo.

551.510.535 : 550.389 731

The Effect of the Magnetic Equator on the Ionization of the E_s Layer.—K. Rawer. (*C. R. Acad. Sci., Paris*, 2nd Nov. 1953, Vol. 237, No. 18, pp. 1102–1104.) Observations made at stations at different latitudes in Africa and Europe are analysed. Daytime values of fE_s show a pronounced maximum at the magnetic equator. Observations of the E_s blanketing frequency indicate that the E_s minimum-ionization ceiling is not subject to the effect, which exists only for the ionization clouds.

551.510.535 : 551.55 732

Winds in the Ionospheric Regions.—S. Deb. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 28–43.) A model for the region between 100 and 400 km height is constructed from considerations of the temperature gradients and the observed wind velocities. According to this model, the wind is south-west in the E and F_1 regions and north-east or east in the F_2 region; its velocity increases from 50 m.p.h. at 100 km to 200 m.p.h. at 200 km. There is a seasonal variation in the magnitude of the velocity, but the model does not involve any diurnal or seasonal changes of direction such as have been reported by observers.

551.510.535 : 621.396.11 733

Results relating to the Critical Frequency and the Transmission Factor of the Ionosphere F_1 Layer.—Theissen. (See 831.)

551.594.4 : 621.396.11 734

A Note on Auroral Interaction.—N. C. Gerson. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 81–82.) The modulation of a radio wave due to a moving auroral reflecting screen is discussed.

LOCATION AND AIDS TO NAVIGATION

621.396.93 735

H.F. Direction Finding.—S. B. Smith & H. G. Hopkins. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 11–14.) A comparison is made of the error components with (*a*) pulse transmissions and (*b*) c.w. transmissions, with particular reference to the performance of Adcock c.r. direction finders operating at frequencies near 8 Mc/s and in the absence of a ground ray. The results presented refer to transmission distances from about 400 to 2 000 km and indicate that pulse operation will normally be at least as accurate as c.w. operation; in the most favourable circumstances for pulse operation (i.e. when a direct first-order echo via the E or E_s layer can be used) the expected ratio of pulse variance to c.w. variance is about 1/3 for single snap bearings.

621.396.93 736

An Analysis of Errors in Long-Range Radio Direction-Finder Systems.—J. G. Holbrook. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1747–1749.) A rigorous mathematical analysis is made of errors usually encountered with a newly installed fixed Adcock d.f. station. The effect of variations in the aerial spacing is discussed particularly.

621.396.96 737

A Theory of Target Glint or Angular Scintillation in Radar Tracking.—R. H. Delano. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1778–1784.) "A theory is presented to describe the statistical aspects of tracking a complex isolated structure, such as an aircraft or naval vessel, by radar. The results are expressible in simplest form when the target subtends an angle small compared with the beamwidth. Other situations require special consideration and treatment, but can be attacked by the same general methods. However, when the angle subtended by the target is small, a single description applies to all radar tracking systems. An apparent and an effective radar center are defined and their statistical properties derived. Special treatment is given to additional noise arising in conical scanning due to amplitude fluctuations as such. The theory provides information relating to the spectra as well as to the probability densities and r.m.s. values of the pertinent quantities. It must be understood that the theory is approximate, is based on a particular model of the target, and leaves the determination of certain critical parameters to experiment in the case of any particular target."

621.396.96 738

The Effective Number of Pulses per Beamwidth for a Scanning Radar.—L. V. Blake. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, p. 1785.) Addendum to paper noted in 2671 of 1953.

621.396.96 : 551.578 739

Radar Displays of Atmospheric Precipitation.—B. Birardi. (*Alta Frequenza*, June/Aug. 1953, Vol. 22, Nos. 3/4, pp. 146–160.) Theory of the reflection of radio waves by precipitation is presented and an illustrated description is given of results obtained at the Research Centre for Microwave Physics at Florence. The future research programme is outlined.

621.396.96 : 621.39.001.11 740

Radar Detection and Information Theory.—U. Tiberio. (*Alta Frequenza*, June/Aug. 1953, Vol. 22, Nos. 3/4, pp. 161–183.) Radar operation is analysed by a statistical method; errors in range and direction are considered. The common ground between the theory of radar and communication is demonstrated by a discussion of automatic and Doppler-effect radar systems.

621.396.962.3 : 621.396.812.3 741

Interpretation of the Fluctuating Echo from Randomly Distributed Scatterers: Part 1.—J. S. Marshall & W. Hitschfeld. (*Canad. J. Phys.*, Sept. 1953, Vol. 31, No. 6, pp. 962–994.) The random fluctuations in the radar echo are investigated statistically and by analogue computation. The results are interpreted in terms of physical methods of reducing their effect. Thus, continuous averaging and limited averaging by the receiver or the A-scope display tube (by superposition of traces) is considered. The precision and the method of measurement of the intensity of the echo from steady and moving targets against a fluctuating noise background are also discussed.

World Radio History

621.396.962.3 : 621.396.812.3 : 551.578 **742**

Interpretation of the Fluctuating Echo from Randomly Distributed Scatterers: Part 2.—P. R. Wallace. (*Canad. J. Phys.*, Sept. 1953, Vol. 31, No. 6, pp. 995–1009.) Echoes from atmospheric precipitation are considered. The method of averaging independent signals is compared with that of continuous averaging. With frequency variation, effectively independent observations from a given region can be obtained. The variation of the signal as the reflection region recedes continuously or as the beam sweeps laterally, is studied. The Markoff method is used throughout. Part 1: 741 above.

621.396.963.3 **743**

Information Cells on Intensity-Modulated C.R.T. Screens.—D. Levine. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1766–1768.) Analysis of screen excitation is based on the assumption that the distribution of the electrons across the beam is Gaussian. It is assumed that two identical radar pulses are just resolvable when they are spaced on the screen so that the crossover of their charge distributions occurs at 40% of the peak intensity; the distance between the 40% points defines the size of the 'information cell'. A specific number of information cells is associated with each type of c.r. tube for a given pulse length and maximum beam current.

621.396.963.8 **744**

Passive Radar Responder.—L. de Magondeaux & R. de Magondeaux. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 533–539.) The arrangement described consists essentially of a resonator associated with a crystal which, when excited by incident pulses of radiation at a resonance frequency, re-radiates between these pulses the energy abstracted from them. In its simplest form the resonator comprises a $\lambda/2$ dipole with the crystal at its midpoint. Using a quartz crystal with a fundamental frequency of 40 Mc/s, the highest practical operating frequency is the harmonic at 200 Mc/s. Possible applications are discussed under three headings, namely (*a*) those based on the individual character of the response, (*b*) those making use of the time delay of the response, and (*c*) those involving modulation of the response.

621.369.969.11 **745**

Doppler-Effect Omnirange.—P. G. Hansel. (*Proc. Inst. Radio Engrs.*, Dec. 1953, Vol. 41, No. 12, pp. 1750–1756.) An omnirange is described in which the transmitting aerial is caused either to move or to appear to move along a circular path, thus producing low-deviation f.m. by Doppler effect. Deviation expansion and selective degeneration in an a.f.c. circuit are used at the receiver to detect the directional signal in the presence of f.m. noise. Advantages claimed for the system include improved resolution, accuracy and ease of multiplexing.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.787.6/.7 **746**

High-Resolution Micromanometer.—(*Tech. News Bull. nat. Bur. Stand.*, Sept. 1953, Vol. 37, No. 9, pp. 140–142.) An instrument designed by Perls, Kaechale & Goalwin, and capable of measuring differential pressures down to 0·03 μ of Hg, uses a capacitance-type pickup with a thin diaphragm and a capacitance bridge driven by a 500-kc/s oscillator.

533.56 **747**

A Portable High-Vacuum System.—V. C. DeMaria. (*Sylvania Technologist*, Oct. 1953, Vol. 6, No. 4, pp. 96–97.) Outline description of a portable diffusion pump suitable for maintaining pressures down to $\sim 10^{-6}$ mm Hg.

535.215.3 : 538.639 : 546.289 **748**

Photoelectromagnetic and Photodiffusion Effects in Germanium.—T. S. Moss, L. Pincherle & A. M. Woodward. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 743–752.) When a slab of Ge is illuminated, a potential gradient is created in the direction of illumination, due to the difference between the electron and hole mobilities (photodiffusion effect). If a magnetic field is applied perpendicular to the direction of illumination, a potential gradient is created in the direction perpendicular to both field and illumination (photoelectromagnetic effect); voltages as great as 0·5 V have been obtained. The saturation value of the photoelectromagnetic voltage provides a convenient measure of the surface recombination velocity. Theory and experimental details are given.

535.37 **749**

Studies on the Concept of Large Activator Centers in Crystal Phosphors.—J. Ewles & N. Lee. (*J. electrochem. Soc.*, Sept. 1953, Vol. 100, No. 9, pp. 392–407.) A study in three parts, under the headings (*a*) dependence of luminescence efficiency on concentration of activator; size of luminescent centres; (*b*) effects of concentration of activator, of temperature, and of flux on the excitation and emission of CaO:Bi phosphors; (*c*) preparation and properties of CaO phosphors with eleven different activators.

535.37 **750**

The Luminescence of Alkaline-Earth Polysulphides.—H. Gobrecht & D. Hahn. (*Z. Phys.*, 25th Sept. 1953, Vol. 135, No. 5, pp. 523–530.)

537.226 : 546.431.82 **751**

The Dielectric Properties of Barium-Titanate Single Crystals in the Region of their Upper Transition Temperature.—L. E. Cross. (*Phil. Mag.*, Oct. 1953, Vol. 44, No. 357, pp. 1161–1170.) A determination was made of the ferroelectric hysteresis and the dielectric constant over the temperature range 20°–150°C. The ferroelectric transition in untwinned crystals, at $\sim$ 120°C, is a thermodynamically first order transition; in twinned crystals different regions transform at different temperatures. In untwinned crystals hysteresis is reintroduced at temperatures in a small range above the transition temperature by application of a sufficient electric field. The forms of the hysteresis figures are explained in terms of Devonshire's theory (663 of 1950).

537.226.2 : 537.29 : 621.315.616 **752**

Variations of the Dielectric Constant of some Plastics as a Function of the Electric Field.—G. Mesnard & L. Eyraud. (*C. R. Acad. Sci., Paris*, 30th Nov. 1953, Vol. 237, No. 22, pp. 1406–1407.) Measurements made using a double-heterodyne method are outlined; the material under test constituted the dielectric of a capacitor in a Hartley oscillator circuit, and was subjected to a unidirectional electric field of variable strength. Relative variations of the order of 5×10^{-6} in the value of the dielectric constant could be detected. Results obtained with vinyl chloride, polyethylene, cellophane and other plastics are reported.

537.311.33 **753**

A More Exact Treatment of the Equations describing Dielectric Relaxation and Carrier Motion in Semiconductors.—J. Keilson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1198–1200.) An exact treatment of the linearized equations of hole and electron flow in a

World Radio History

homogeneous semiconductor leads to an expression for the polarization attributable to local variations in conductivity. The corrections to the previously obtained values for the effective mobility and the diffusion coefficient are of the order of τ_r/τ where τ_r is the relaxation time and τ is the lifetime. These corrections are negligible for semiconductors.

537.311.33 : 546.281.26 **754**

The Infrared Absorption Spectrum of Silicon Carbide.—A. K. Ramdas. (*Proc. Indian Acad. Sci. A*, April 1953, Vol. 37, No. 4, pp. 571–577.) The transmission spectra of 12 specimens were studied over the range 1–20 μ. The results are discussed in relation to X-ray determinations of the structure.

537.311.33 : 546.289 **755**

Thermal Acceptors in Vacuum-Heat-Treated Germanium.—S. Mayburg & L. Rotondi. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1015–1016.) The Ge single-crystal specimen was heated by passing a current directly through it, and was cooled by radiation. The value found for the concentration of acceptors differed by as much as a factor of 80 from results reported by workers using other methods of vacuum heat treatment. Reasons are advanced for concluding that the observed acceptors are lattice vacancies and not impurity atoms.

537.311.33 : 546.289 **756**

Infrared Absorption of *p*-type Germanium.—W. Kaiser, R. C. Collins & H. Y. Fan. (*Naturwissenschaften*, Sept. 1953, Vol. 40, No. 18, p. 479.) Measurements were made over the wavelength range 1·5–35μ, using specimens with resistivities from 0·04 to about 10 Ω.cm. The characteristic absorption spectrum obtained at room temperature is much more complex than for *n*-type Ge. Weak absorption bands were found at about 2·9μ and 4·5μ, and a strong wide band centred at about 20μ. Modified curves obtained at 5° and 77°K are also shown and discussed.

537.311.33 : 546.824-31 **757**

Electrical Properties of Titanium Dioxide Semiconductors.—R. G. Breckenridge & W. R. Hosler. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 793–802.) Measurements of resistivity and Hall coefficient in the temperature range − 190°C to + 500°Cwere made on ceramic and single-crystal rutile specimens with resistivities between 0·1 and 100 Ω.cm. From these measurements, which were made for two different crystal orientations, the variations of electron mobility and charge-carrier concentration with temperature were deduced. The mobility data can be explained in terms of scattering, with the effect of lattice vibration predominant at high temperatures, and that of ionized impurities predominant at lower temperatures. A large effective electron mass is deduced from the mobility values, indicating that the specimens were not degenerate in the temperature range studied, in spite of the large number of charge carriers. The charge-concentration variation found suggests that two types of donor centres, possibly oxygen ion vacancies, are present.

537.311.33 : 548.55 : 546.682.86 **758**

Hall Effect and Conductivity of InSb Single Crystals.—M. Tanenbaum & J. P. Maita. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1009–1010.) Measurements on three samples over a range of temperatures are reported, a reversal in sign of the Hall coefficient occurring in two cases, at 155° and 182°K respectively. The deduced value of the energy gap at room temperature is 0·18 eV; this is in agreement with that obtained from infrared-absorption measurements.

537.311.33 : 621.314.7 **759**

The Surface-Barrier Transistor: Part 5 — The Properties of Metal-to-Semiconductor Contacts.—Schwarz & Walsh. (See 895.)

537.312.8 **760**

Galvano-Magnetic Effects at High Frequencies.—B. Donovan & E. H. Sondheimer. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 849–851.) A theoretical investigation of the variation of resistivity of a semi-infinite metal with the frequency of an electric field parallel to the surface, in the presence of a magnetic field perpendicular to the surface.

537.533 : 546.78 **761**

Crystallographic Variations of Field Emission from Tungsten.—M. K. Wilkinson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1203–1209.) Emission from a tungsten single crystal was investigated photometrically at pressures around 10^{-12} mm Hg. The experimental method and, in particular, the vacuum technique, are described and the results are tabulated and shown graphically.

537.533.8 : 537.311.33 **762**

Secondary Electron Emission from Impurity Semiconductors.—H. Gobrecht & F. Speer. (*Z. Phys.*, 25th Sept. 1953, Vol. 135, No. 5, pp. 602–614.) Measurements were made on four Ge crystals with different impurities and electrical properties. A monotonic increase up to 7% in the secondary-emission factor was observed to accompany an increase up to $1{\cdot}5 \times 10^3$ in conductivity. This increase is attributed to the increase of impurity concentration accompanying the increased conductivity. The decrease in secondary emission, to be expected as a result of the increased number of charge carriers, is masked. The type of conduction and the nature of the impurity do not affect the secondary emission. Measurements made on Ge and Se evaporated layers with and without impurities confirmed the above results. Secondary-emission curves were also obtained for evaporated layers of the four impurity metals used, namely Ga, Sb, Tl and Bi.

538.221 **768**

On the Nature of Ferromagnetism in Pyrrhotite.—K. Alexopoulos & A. Theodossiou. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 753–759.)

538.221 **764**

A Study of Bitter Figures on the (110) Plane of a Single Crystal of Nickel.—L. F. Bates & G. W. Wilson. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 819–822.)

538.221 **765**

A Proposed Structure for Certain Domain Configurations on a Single Crystal of Nickel.—G. W. Wilson. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 840–841.)

538.221 **766**

Microwave Resonance Absorption in some Ferromagnetic Manganese Compounds.—G. D. Adam & K. J. Standley. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 823–835.)

538.221 **767**

Magnetic Viscosity in Platinum Cobalt.—A. W. Simpson & R. H. Tredgold. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 805–807.) Experimental results indicate that this alloy obeys the general relation for ferromagnetic materials found by Barbier (1661 of 1950).

World Radio History

538.221 768

Magnets and Magnetism — Recent Developments.—W. Sucksmith. (*Brit. J. appl. Phys.*, Sept. 1953, Vol. 4, No. 9, pp. 257–262.) Ferromagnetic materials, including oxides, are discussed.

538.221 769

Measurement of Permeability Tensor in Ferrites.—J. O. Artman & P. E. Tannenwald. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1014–1015.) Preliminary report on an experimental method of determining the off-diagonal tensor components of permeability which involves the splitting of degenerate cavity modes in a magnetic field.

538.221 770

A Comparison of the Powder Patterns on a Sample of Grain-Orientated Silicon-Iron with those obtained on a Single Crystal.—L. F. Bates & A. Hart. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405A, pp. 813–818.)

538.221 771

The Permeability of Silicon-Iron.—E. Both. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, p. 797.) Digest only. The Si/Fe alloy described has an initial permeability of 1 500 and an incremental permeability value $\sim 0{\cdot}5\%$ per millioersted; the corresponding values for Ni/Fe alloys are 2 000 and 0·2%.

538.247 : 621.318.2 772

Investigations of Aging Processes in Permanent Magnets.—K. J. Kronenberg. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 321–329.) The changes in remanence due to the application of direct and alternating magnetic fields and a variation in the form factor by short-circuiting with a soft iron bar, were investigated experimentally and the results are presented graphically. The magnets investigated were made of tungsten steels, cast and sintered alnic, alnico and iron dust. The remanence of alnic alloys, the most stable magnets, decreased with increase in the number of demagnetizations and with increase in the storage time in the magnetized state. An increase in remanence with storage times was observed in certain cases.

539.23 : 546.87 : 535.215.1 773

The Photoelectric Effect of Thin Bi Films.—D. J. Fourie. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, p. 803.) The variation of photoelectric current observed when d.c. is passed through the film depends on the direction and magnitude of the current but is not a pure heating effect since the passage of a.c. does not cause the same variation.

539.23 : 546.46-31 : 537.533.8 774

The Mechanism of Self-Sustained Electron Emission from Magnesium Oxide.—D. Dobischek, H. Jacobs & J. Freely. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 804–812.) Continuation of work reported in 998 of 1953 (Jacobs et al.). When higher fields are applied, the secondary-emission current becomes very much larger and increasingly independent of the bombarding current, and, under certain conditions, persists for many hours after the bombarding current has been switched off. This enhanced emission has two components. The first is a true field-enhanced secondary-emission effect similar to that previously described. The second component is a self-sustained electron emission produced by the same type of avalanche effect, except that the internal ionization of the dielectric is initiated by electrons produced from within the material.

546.26 775

The Formation of Black Carbon.—R. O. Grisdale. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1082–1091.) Electron-microscope evidence is presented in support of the hypothesis that black carbon resulting from pyrolysis of gaseous hydrocarbons is produced through the intermediate formation of droplets of complex hydrocarbons. It appears that the process is fundamentally similar to that for obtaining carbon by the carbonization of solids.

546.321.85 : 537.226 776

The Properties of Colloidal Ferroelectric Materials: Part 1 — Potassium Phosphate (KH_2PO_4).—C. Jaccard, W. Känzig & M. Peter. (*Helv. phys. Acta.* 15th Sept. 1953, Vol. 26, No. 5, pp. 521–544. In German.) An isolated and nonconducting ferroelectric crystal of approximately spherical shape cannot become polarized spontaneously, if forced to form a single domain, since the energy of the surface charges would exceed the polarization energy. For small crystals, the wall energy prevents splitting into domains; hence a critical size exists, below which spontaneous polarization cannot occur. This was observed in KH_2PO_4 crystals of diameter $<1\,500$ Å embedded in insulating media of dielectric constant $\epsilon \leqslant 5$; crystals of diameter $>4\,000$ Å showed normal ferroelectric properties. The critical diameter decreases with increasing ϵ; in a conducting medium even 500 Å crystals showed normal spontaneous polarization. The anomaly in the dielectric constant of crystals smaller than the critical size at $1{\cdot}0 \pm 0{\cdot}5$ °C below the Curie temperature, is probably not due to an anti-ferroelectric transition.

546.817.231 : 537.312.5 777

"Phosphorescent" Effect in Lead Selenide.—P. A. Lee. (*Canad. J. Phys.*, Sept. 1953, Vol. 31, No. 6, pp. 1023–1024.) Brief report of measurements of the conductivity of a thin layer of PbSe on illumination, at 90 K, by tungsten light. The effect observed is similar to that noted in PbS by Chasmar & Gibson (3156 of 1951).

621.314.634.012.6 778

Contribution to the Knowledge of Dynamic Phenomena in the Selenium Rectifier.—H. Lauckner. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 341–349.) Current creep was investigated experimentally in Se rectifiers with, and without, a lacquer intermediate layer. The results are in agreement with the mobile charge-carrier hypothesis on the assumption that small field changes due to slow ion movements result in large inverse-current changes. The rapid current response to a step voltage in the lacquer-layer type is due to the inhibition of ion movement at the Se grain boundaries.

621.315.6 779

Recent Progress in Dielectrics.—(*Nature, Lond.*, 26th Sept. 1953, Vol. 172, No. 4378, pp. 563–564.) Brief account of the discussions at the meeting of the British Association, Section A, in Liverpool, September 1953.

621.315.61.029.4/.53 780

Maxwell-Wagner Loss and Absorption Currents in Dielectrics.—B. V. Hamon. (*Aust. J. Phys.*, Sept. 1953, Vol. 6, No. 3, pp. 304–315.) The dielectric loss factor of mixtures consisting of a nonpolar base material and a small amount of a slightly conducting solid or liquid 'impurity', was measured at frequencies up to 3 Mc/s. 'Impurities' in the form of small spheres and in the form of a fine powder covering the surfaces of the grains of the base material were studied. The effect of direct and alternating potential gradients on the conductivity and loss factor of the mixtures was also investigated. The results are shown graphically, compared with theoretical results and with published data for practical dielectrics.

World Radio History

621.315.611 781

Experimental Contribution to the Study of the Dielectric Strength of Solid Insulators.—P. Dubois & R. Hérou. (*Rev. gén. Élect.*, Sept. 1953, Vol. 62, No. 9, pp. 438–441.) Report of experiments carried out at the Laboratoire central des Industries électriques to determine the influence of electrode shape and insulator thickness.

621.315.612 782

Phase Transitions in Antiferroelectric $PbHfO_3$.—G. Shirane & R. Pepinsky. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 812–815.) $PbHfO_3$ is antiferroelectric below 163 °C and has an intermediate phase between 163°C and 215°C which is also antiferroelectric, with a different type of dipole arrangement from that of the lowest phase. At 215 °C $PbHfO_3$ becomes paraelectric, and its structure changes from the tetragonal to the cubic type.

621.315.612.4 : 621.317.733 783

Some Dielectric Properties of Barium-Strontium Titanate Ceramics at 3 000 Mc/s.—L. Davis, Jr, & L. G. Rubin. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1194–1197.) Measurements at 10 kc/s, 500 kc/s and 3 kMc/s indicate that the dielectric constant is independent of frequency at temperatures above the Curie temperature. The effects of electric field strength and temperature on the dielectric constant and the loss tangent were also investigated. The results are shown graphically. The 3-kMc/s bridge is described.

621.315.613.1 784

Synthetic Mica Investigations: Part 1 — A Hot-Pressed Machinable Ceramic Dielectric.—J. E. Comeforo, R. A. Hatch, R. A. Humphrey & W. Eitel. (*J. Amer. ceram. Soc.*, 1st Sept. 1953, Vol. 36, No. 9, pp. 286–294.) The properties and the manufacture of a new ceramic composed entirely of synthetic fluorine-mica are described. Extensive ionic-replacement possibilities permit a large range of variation in the properties, and tables and graphs for the electrical and mechanical characteristics of several types are given. Thus, $BaMg_3Al_2Si_3O_{10}F_2$ has a water absorption $< 0{\cdot}1\%$, density 3·51 g.cm^{-3}, power factor 0·0003, dielectric constant 7·6 and loss factor 0·0022 at 1 Mc/s. The effect of an increase of temperature up to 250 °C is small. The transverse strength is $> 8\,000$ lb/in^2.

621.315.616 785

Dielectric Properties of Teflon from Room Temperature to 314°C and from Frequencies of 10^2 to 10^5 c/s.—P. Ehrlich. (*J. Res. nat. Bur. Stand.*, Oct. 1953, Vol. 51, No. 4, pp. 185–188.) Measurements indicate that the dielectric constant decreases slightly with increasing temperature and is independent of frequency at all temperatures.

621.318.22 : 538.221 786

The Coercive Force of Magnets moulded from Very Fine Co-Fe Powders.—F. Lihl. (*Acta. phys. austriaca*, July 1953, Vol. 7, No. 3, pp. 239–247.) Continuation of work noted previously (1935 of 1952). Coercive force, remanence and *BH* product increase with Co content; the practically attainable optimum values are not yet reached for 36·4% Co. The positions of the maxima of coercive force and *BH* product, with respect to variations of reduction time and degree depend on the composition; for a given composition the positions of these maxima depend on the powder preparation and moulding processes. Extrapolation to the case of infinitely low density gives lower values of the coercive force than would be expected from Néel's theory, but indicates the highest practically attainable values.

621.791 : 546.621 787

Joining Aluminum to Other Materials.—M. A. Miller. (*Mater. & Meth.*, Sept. 1953, Vol. 38, No. 3, pp. 96–99.) Methods appropriate to various materials, component designs and service requirements are described.

621.92 : 549.514.51 : 621.372.412 788

The Production of Very Thin Quartz Oscillator Plates.—J. E. Thwaites & C. F. Sayers. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 105–107.) Account of the construction and operation of a machine for lapping plates to a thickness of about 0·055 mm.

666.1 789

Glass in the Electronic Industry.—M. Manners. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 512–516.) The various types of glass available are reviewed and their particular applications indicated, with special reference to problems of sealing. Tables show the composition and properties of some of the most common glasses and some combinations of glass and metal for making seals.

MATHEMATICS

511 : 53 : 621.39 790

Radio Technology and the Theory of Numbers.—B. van der Pol. (*J. Franklin Inst.*, Sept. 1953, Vol. 256, No. 3, p. 265.) Correction to paper noted in 3346 of 1953.

513.761.22 : 621.372 791

Geometric Construction of the Homographic Transformation.—P. Mourmant. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 540–542.) A discussion of the geometric properties of the homographic transformation $Z = \alpha(\beta + z)/(\gamma + z)$, giving generalized impedance in terms of the complex coefficients α, β and γ and elementary impedance z.

517.6 792

Evaluation of the Integral $\int_0^\infty e^{-u^2-x/u}\,du$.—M. Abramowitz. (*J. Math. Phys.*, July/Oct. 1953, Vol. 32, Nos. 2/3, pp. 188–192.) The integral studied appears in various physical problems involving particles with Maxwellian distribution of velocities.

518.2 : 517.564 793

Radix Table for obtaining Hyperbolic and Inverse Hyperbolic Functions to Many Places.—H. E. Salzer. (*J. Math. Phys.*, July/Oct. 1953, Vol. 32, Nos. 2/3, pp. 197–202.)

MEASUREMENTS AND TEST GEAR

53.08 : 621.39.001.11 794

The Negentropy Principle of Information.—L. Brillouin. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1152–1163.) The statistical definition of information is compared with Boltzmann's formula for entropy. The relations between the information obtained and the cost in entropy (or money) in the measurement of very small quantities are derived and applied to a consideration of the accuracy and efficiency of measurements.

621.317 : 621.396.82 795

Radio Interference.—(*Elect. Rev., Lond.*, 11th Sept. 1953, Vol. 153, No. 11, p. 563.) A note of British Standards on interference measurements and of Electrical Research Association Reports Ref. M/T 116 and 117 describing appropriate measurement equipment.

World Radio History

621.317.089.6 796

Practical Calibration Adjustments for Apparatus which Obeys a Theoretical Law Imperfectly.—J. W. Head. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 499–501.) Description of a method devised for calibrating a tone source for which the dial angle ϕ was theoretically related to the frequency f by the formula $\phi = A + B \log_{10} f$. The object was to obtain easily a calibration curve sufficiently smooth and accurate for practical purposes, rather than to find the unique curve satisfying some mathematical criterion of goodness of fit.

621.317.3 : 621.396.822 797

Valve and Receiver Noise Measurement at V.H.F.—N. Houlding. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 15–26.) Techniques for the measurement of noise factor, valve noise and other parameters involved in the investigation of receiver noise performance are described. Sources of error, and precautions required to minimize errors, are discussed. Equipment giving improved accuracy is described. Some measurements on noise generators and valve noise are reported.

621.317.32 : 621.385.832 798

Measurement of Voltage using a Simple Electron-Beam Valve.—A. Lieb. (*Funk u. Ton*, Sept. 1953, Vol. 7, No. 9, pp. 463–471.) A detailed description is given of a valve of magic-eye type adapted to indicate the adjustment of a variable voltage to a desired setting. Two luminescent streaks, produced by independent beam-forming electrode systems, are brought into coincidence when the adjustment is correct.

621.317.33 : 621.372.413 799

Measurement of Resonant-Cavity Characteristics.—G. L. Hall & P. Parzen. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1769–1773.) The system considered is a re-entrant cavity terminating a coaxial line. A method of determining the loaded and unloaded Q and the shunt resistance of the cavity is described, involving measurements of frequency shifts caused by introducing a small obstacle into the cavity. A high-stability high-resolution a.f.c. system for controlling the klystron oscillator is described.

621.317.333.6 : 621.372.8 800

A Standard Waveguide Spark Gap.—D. Dettinger & R. D. Wengenroth. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 39–48.) Description and comparison of four types of spark gap used for testing the power-handling capacity of waveguides, namely (*a*) resonant-section, (*b*) swayback, (*c*) cylindrical-bump, (*d*) hemispherical-bump types.

621.317.335.3 + 621.317.411 801

Optical Methods for Measurement of Complex Dielectric and Magnetic Constants at Centimetre and Millimetre Wavelengths.—T. E. Talpey. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 561–569.) Modifications necessary to take account of loss factors in basic formulae relating to transmission and reflection of a plane wave incident on a reflecting plate are discussed. Using formulae derived, permittivity k_e, permeability k_m and loss angles δ_e, δ_m can be determined, when losses are small, from (*a*) Brewster angle and transmission and reflection coefficients at this angle of incidence, when the plane of polarization is parallel to the plane of incidence, (*b*) the ratio of the moduli of the reflection coefficients with polarization parallel to and normal to the plane of incidence, (*c*) plate thickness and wavelength. Equipment for measuring these quantities comprises a klystron oscillator with associated wavemeter, attenuator and horn radiator, a receiver with horn attenuator and detector, and a rotatable support for the sample. Experimental results for bakelite, glass, polystyrene and paraffin at λ 8·36 mm are quoted.

621.317.34 : 621.372.8 802

Precision Measurement of Waveguide Attenuation.—J. H. Vogelman. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 196–199.) A method of determining attenuation values between 0·01 and 0·5 db, and down to 0·001 db with lower accuracy, is based on standing-wave measurements. The technique is useful for investigating the influence of the waveguide surface condition on the attenuation.

621.317.341.029.62/.65 803

Audio Modulation Substitution System for Microwave Attenuation Measurements.—J. Korewick. (*Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 14–21.) An arrangement for measuring attenuations up to 40 db over the frequency range 240 Mc/s–40 kMc/s uses an audio-modulated klystron oscillator as a stable r.f. source and a barretter as a square-law detector. Attenuation produced in the microwave section by the system under test is compensated by adjustment of a standard attenuator in the audio section, the output level being held constant.

621.317.361.029.64 804

Techniques of Frequency Measurement in the Centimetre-Wave Region.—E. G. Hope. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 144–153. Digest, *ibid.*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 383–384.) Methods developed at the National Physical Laboratory and based on the 100-kc/s quartz-crystal standard are discussed. Frequencies up to 50 kMc/s can be measured with an error $<$ 1 part in 10^8. For producing the required standard frequencies in the centimetre-wave range, crystal diodes are used as harmonic generators. The properties of a number of types of crystal diode have been investigated and the optimum values of input power and bias voltage determined. Most types of Si diode and several types of Ge diode are suitable, the Ge types in general requiring less input power for the same harmonic output. On the basis of measurements, an approximate formula is derived for predicting the power in a given harmonic.

621.317.7 : 621.395.822 805

A Mains-Operated Psophometer.—F. H. Goldsmith & J. A. Widdicks. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 112–114.) The psophometer is essentially a valve voltmeter measuring the r.m.s. voltage of a complex a.f. signal and incorporating a frequency-weighting network. An experimental model is described in which the overall error is $< 3\%$.

621.317.723 806

Portable Quadrant Electrometer of High Sensitivity.—G. F. Schilling & P. Kreager. (*Rev. sci. Instrum.*, Sept. 1953, Vol. 24, No. 9, pp. 877–878.) Description of an instrument developed in connection with the study of atmospheric electricity.

621.317.73 : 546.28 + 546.289 807

Four-Probe Instrument for Resistivity Measurements of Germanium and Silicon.—A. L. MacDonald, J. Soled & C. A. Stearns. (*Rev. sci. Instrum.*, Sept. 1953, Vol. 24, No. 9, pp. 884–885.) A brief description of the construction of the instrument is given.

621.317.733 : 621.315.612.4 808

Some Dielectric Properties of Barium-Strontium Titanate Ceramics at 3 000 Mc/s.—Davis & Rubin. (See 783.)

World Radio History

621.317.763.029.64/.65 809

A Microwave Fabry-Perot Interferometer.—J. O. Artman. (*Rev. sci. Instrum.*, Sept. 1953, Vol. 24, No. 9, pp. 873–875.) Details are given of an interferometer for measurements in the wavelength range 5 mm–4 cm, using a movable totally reflecting surface parallel to a fixed partially reflecting surface composed of elements (e.g., metal balls) whose dimensions are much smaller than λ. A magic-T waveguide junction takes the place of the beam-splitting plate of the optical system.

621.317.78.029.6 : 536.62 810

Accurate R.F. Power Measurements.—R. M. Soria & J. G. Krisilas. (*Radio & Telev. News, Radio-Electronic Engng Section*, Sept. 1953, Vol. 50, No. 3, pp. 3–6, 29.) Continuous-flow calorimetric methods are used for r.f. power output measurements, in the range 2 W–5 kW, and for the calibration of input-power indicators. The power-indicator component calibrated is isolated electrically from the thermocouple inserted in it by means of a quarter-wave transformer. Constructional details of the equipment used and performance curves are given.

621.397.621.2.001.4 811

Simple Linearity-Measuring Instrument.—K. G. Beauchamp. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 36–37.) A device on the lines of a travelling microscope is described for measuring the distance between pairs of parallel bars of a test pattern at different parts of the screen face.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.77 : 621.383 812

A Photoelectric Decimal-Coded Shaft Digitizer.—W. H. Libaw & L. J. Craig. (*Trans. Inst. Radio Engrs*, Sept. 1953, Vol. EC-2, No. 3, pp. 1–4.) A device is described for giving an indication of the position of a rotating shaft. Lamps illuminate photocells arranged round the shaft, in accordance with the position of slits in a screen attached to the shaft. Details are given of a decade system.

538.569.2.047 813

Capacity and Conductivity of Body Tissues at Ultrahigh Frequencies.—H. P. Schwan & Kam Li. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1735–1740.) Results of measurements over the frequency range 200–1 000 Mc/s are analysed, and the variations are explained on a biological basis. Temperature variations are also investigated. Measuring technique is described.

621.316.729 814

Cathode-Ray Synchroscope and Automatic Synchronizer.—M. A. H. Ahmed. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, p. 808.) Summary only. Two voltages are compared for synchronism by applying them to a c.r. tube so that one produces a circular trace while the other produces radial pips. Automatic synchronization is obtained by using a c.r. tube with a two-electrode target in conjunction with a relay system.

621.317.083.7 : 621.396.91 815

Automatic Radio Equipment for Long-Period Operation for Long-Range Transmissions of Weather Data.—E. Plötze, K. Rawer & E. Stoebe. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 351–359.) Equipment for short-wave meteorological stations for use on sea or land is described. Operational experience with equipment used in the Arctic and the Atlantic regions is discussed.

621.319.339 816

The Design of the Electric Field in a Van de Graaff Generator.—J. W. Boag. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 63–82.)

621.319.339 : [621.398 + 621.317.083.7 817

A Remote Control and Telemetering System for a Van de Graaff Generator.—B. Millar. (*Electronic Engng*, Nov. & Dec. 1953, Vol. 25, Nos. 309 & 310, pp. 446–450 & 506–508.) A system using modulated light beams is described.

621.384.611 818

Vertical Focusing in the Microtron.—J. S. Bell. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 802–804.) A theoretical study is made of the vertical focusing oscillations. See also 2090 of 1953 (Henderson et al.).

621.384.612 819

Stability of Orbits in a Strong-Focusing Synchrotron.—S. Lundquist. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 981–983.)

621.384.612 820

Proton Synchrotron of the University of Birmingham.—(*Nature, Lond.*, 17th Oct. 1953, Vol. 172, No. 4381, pp. 704–706.) Preliminary tests of the machine are reported. See also 700 of 1951 (Hibbard).

621.384.612 821

The Cosmotron — a Review.—M. H. Blewett (Ed.). (*Rev. sci. Instrum.*, Sept. 1953, Vol. 24, No. 9, pp. 725–870.) A series of papers covering all aspects of the Brookhaven proton synchrotron.

621.385.83 : 621.317.329 + 517.944 822

Electrostatic Potential Plotting for Use in Electron-Optical Systems.—Kuo-Chu Ho & Moon. (See 912.)

621.385.833 823

A Method for the Direct Measurement of the Caustic Surfaces of Electron Lenses.—W. Scheffels, M. Hahn & F. Lenz. (*Optik, Stuttgart*, 1953, Vol. 10, No. 9, pp. 455–458.)

621.385.833 824

Correction of Electrostatic Lenses by Departure from Rotational Symmetry.—J. C. Burfoot. (*Proc. phys. Soc.*, 1st Sept. 1953, Vol. 66, No. 405B, pp. 775–792.)

621.385.833 825

Determination of Focal Lengths of Unipotential Lenses by the Rotating-Beam Method.—R. V. Jordan, D. W. Shipley & M. Krawitz. (*Sylvania Technologist*, Oct. 1953, Vol. 6, No. 4, pp. 92–95.) Measurements were made on a three-cylinder unipotential lens modified by inserting apertured diaphragms, by varying the length of the focusing (middle) cylinder, and by varying the spacing between the cylinders. The results are shown graphically.

621.387.424 : 550.8 826

Electronic Equipment used for Geological Research at Depth by Radioactivity Methods.—J. Berbezier. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 553–560.) The equipment comprises a G-M-counter probe lowered down the bore-hole on a cable, an automatic depth recorder, pulse integrator and recorder. Records reproduced show the natural and the neutron-induced gamma radiation from different strata at depths down to 680 m.

621.387.424 : 550.8 827

Radioactivity Method of Prospecting for Uranium Ores.—C. Lallemant. (*Onde élect.*, Oct. 1953, Vol. 33, No. 319, pp. 547–552.) Review of the technique, including descriptions and circuit details of French equipment for the detection and measurement of radioactivity.

World Radio History

PROPAGATION OF WAVES

538.566 : 535.42 828

Diffraction of Electromagnetic Waves near the Earth's Surface in an Optically Inhomogeneous Medium.—R. Schachenmeier. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, p. 491.) Correction to paper abstracted in 238 of 1952.

621.396.11 : 550.38 : 551.510.535 829

Measurements of the Terrestrial Magnetic Field in the E-Layer.—Cutolo. (See 720.)

621.396.11 : 551.510.535 830

Prediction of Ionospheric Propagation for Distances greater than 10 000 km.—E. Harnischmacher. (*C. R. Acad. Sci., Paris*, 2nd Nov. 1953, Vol. 237, No. 18, pp. 1071–1073.) The method discussed is developed from that previously described by Rawer (199 of 1953) and is based on the assumption that in very-long-distance propagation reflections occur at both F and E layers; the total number of hops is greater than for pure F-layer propagation and the absorption is therefore higher, but the blanketing effect of the E and E_s layers is eliminated. The values of the different possible angles of departure are close together for very-long-distance circuits, and the wave in effect adapts its path to the ionospheric conditions along the route. Experimental results obtained on a 17 000-km path confirm predictions made on this basis.

621.396.11 : 551.510.535 831

Results relating to the Critical Frequency and the Transmission Factor of the Ionosphere F_1 Layer.—E. Theissen. (*C. R. Acad. Sci., Paris*, 2nd Nov. 1953, Vol. 237, No. 18, pp. 1104–1106.) Using values measured at Freiburg in the formula $f_0F_1 = k\cos^n z$ (z is the zenithal angle of the sun, k is the critical frequency for $z = 0$) the mean value of n for the months March–September was found to be 0·22. No seasonal or eleven-yearly variation of its value was found. The value of k depends on the sunspot number. The F_1 transmission factor (M3000) has a diurnal and seasonal variation represented by $M_0\cos^m z$, the value of m being $0{\cdot}08 \pm 0{\cdot}02$. The observations also indicate that the F_1 layer rises as solar activity increases.

621.396.11 : 551.594.5 832

A Note on Auroral Interaction.—N. C. Gerson. (*J. atmos. terr. Phys.*, Sept. 1953, Vol. 4, Nos. 1/2, pp. 81–82.) The modulation of a radio wave due to a moving auroral reflecting screen is discussed.

621.396.81.029.62 : 551.593 833

The Increase of U.S.W. Field Strength due to a Refracting Tropospheric Layer (Inversion).—R. Schachenmeier. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 485–491.) Expressions are derived for the effect of an inversion layer on the field strength at points beyond the horizon. A practical example is worked out. When the receiving aerial is far beyond the horizon and the inversion layer lies below the transmitting aerial, the field strength is increased.

621.396.812.029.62/.63 834

Investigation of the Influence of the Troposphere on the Propagation of Ultra-short Waves.—R. Schachenmeier. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, p. 491.) Correction to paper abstracted in 2524 of 1951.

RECEPTION

621.376.233 : 621.314.632 835

Crystal-Mixer Design at Frequencies from 20 000 to 60 000 Mc/s.—Ditchfield. (See 890.)

621.396.621 : 621.314.7 836

Experimental Transistor Receiver.—B. R. Bettridge. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 2–5.) Two two-transistor circuits for local-station reception are described. The total consumption is 6 mA at 18 V; acceptable volume is obtained with an input of about 20 mW to a sensitive loudspeaker. Reflexing is used to improve sensitivity in the more elaborate circuit.

621.396.621 : 621.396.822 837

First Probability Densities for Receivers with Square-Law Detectors.—R. C. Emerson. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1168–1176.) A procedure is indicated for using the Kac-Siegert method (3645 of 1947) in its widest generality without the necessity of finding eigenvalues and without dealing with the characteristic function at all; it involves expanding the density function in an orthonormal series, the coefficients of which are expressed in terms of cumulants, which in turn are obtained from the system kernel. A receiver with Gaussian i.f. and Gaussian a.f. pass characteristics is treated in detail.

621.396.621.57 : 621.376.3 : 631.314.7 838

A Portable Transistor F.M.-Receiver.—R. C. Ballard. (*Tele-Tech*, Aug. 1953, Vol. 12, No. 8, pp. 79, 206–207.) Eleven point-contact Ge transistors and four Ge diodes are used in an experimental receiver giving an overall amplification of 67 db and an undistorted output of 75 mW. The collector-current drain is 60 mA. Circuit details are given.

621.396.812.3 839

Evaluation of Polarization Diversity Performance.—J. L. Glaser & L. P. Faber, Jr. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1774–1778.) Experiments on the reduction of fading effects are reported. Measurements were made on unmodulated signals of frequencies 6·985 and 11·66 Mc/s transmitted from Red Bank, N.J., and received near St. Louis, Mo., separate aerials being used to receive the vertically and horizontally polarized components. The results on 11·66 Mc/s were nearly equal to those which would be produced by independent Rayleigh distributions of signal amplitude for the two components. On 6·985 Mc/s the improvement due to the diversity reception was not so great.

621.396.82 : 621.317 840

Radio Interference.—(See 795.)

621.396.828 : 621.327.43 841

Present Position as regards Suppression of Radio Interference from Fluorescent Lamps.—W. Rüegg. (*Bull. schweiz. elektrotech. Ver.*, 5th Sept. 1953, Vol. 44, No. 18, pp. 804–805. Discussion, pp. 805–807.)

551.594.6 : 621.396.822 842

Radio Research Special Report No. 26. Measurements of Atmospheric Noise at High Frequencies during the years 1945-51. [Book Notice]—F. Horner. Publishers: H.M. Stationery Office, London, 1953, 1s. 9d. (*Govt Publ., Lond.*, Sept. 1953, p. 21.)

STATIONS AND COMMUNICATION SYSTEMS

621.39 : 621.376 843

Applications of Polyphase Modulation in Telecommunications.—S. Silleni. (*Poste e Telecomunicazioni*, Sept. 1953, Vol. 21, No. 9, pp. 403–415.) Some particularly difficult filtering problems can be solved by use of polyphase modulation. The basis of the method is explained and applications are described, including a frequency-shift radiotelegraphy system and transmitters

World Radio History

and receivers for s.s.b. radiotelephony. Phase changers, modulators and mixers are described. The usefulness of the system for economizing on bandwidth is indicated. 45 references.

621.39.001.11 **844**

Introduction to Communication Theory.—E. H. Harwood. (*Trans. S. Afr. Inst. elect. Engrs*, Aug. 1953, Vol. 44, Part 8, pp. 241–250.)

621.39.001.11 **845**

Bits, Language Efficiency and Information Theory.—R. L. Shuey. (*Gen. Elect. Rev.*, Sept. 1953, Vol. 56, No. 5, pp. 15–19.) The basic concepts of communication theory are simply explained.

621.39.001.11 : 519.272 **846**

Correlation and Autocorrelation in Communication Engineering.—W. Meyer-Eppler. (*Arch. elekt. Übertragung*, Oct. & Nov. 1953, Vol. 7, Nos. 10 & 11, pp. 501–504 & 531–536.) The common correlation functions and coefficients are defined and their meanings are explained in physical terms. Numerous applications are noted to problems in physics (e.g., interference) and, in particular, to problems in communication and acoustic engineering, e.g., recognition of signals in noise, objective determination of the acoustic quality of a room, etc. Correlatographs are also discussed. Special devices such as a reading apparatus for the blind and a device for the automatic recognition of the spoken word are mentioned. 46 references.

621.395.43/.44 **847**

Interchannel Interference in Multichannel Carrier Telephone Systems.—S. Dossing. (*Telecommun. J. Aust.*, Oct. 1952, Vol. 9, No. 2, pp. 101–108.) Various forms of interchannel interference are described, and methods of measurement are discussed.

621.395.63 : 621.396.5 **848**

Selective Calling for Radio-Telephone Systems.—J. R. Pollard. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 490–496.) R/T systems consisting of a master station and a number of subsidiary stations are considered, and three alternative circuit arrangements are described for use at subsidiary stations to enable individual, group or general calls to be made. Each arrangement includes a pulse-counting section and a discriminator section; dekatrons and/or cold-cathode trigger triodes are used.

621.396.41 : 621.376.3 **849**

Some Recent Developments in the Multiplexed Transmission of Frequency Modulated Broadcast Signals.—E. H. Armstrong & H. J. Bose. (*Proc. Radio Cl. Amer.*, 1953, Vol. 30, No. 3, pp. 3–13.) An account of the two-channel system operated at Alpine, New Jersey (KE2XCC). The main carrier is frequency-modulated by a subcarrier of frequency 27·5 kc/s; both main carrier and subcarrier are individually frequency-modulated with programme material, the maximum deviation of the former being about 50 kc/s and of the latter 5 kc/s. The maximum modulation frequency is 15 kc/s for the main channel and 7·5 kc/s for the second channel. Cross modulation at the transmitter is avoided by keeping the channels separate up to a stage where the normal circuit requirements call for a bandwidth sufficient to ensure good phase linearity. At the receiver, the first discriminator must be carefully designed to avoid introduction of cross modulation. Performance tests are reported; signals received at a level of $< 10\,\mu V$ are intelligible.

621.396.65 : 621.396.41.029.63 **850**

Portable Microwave for Allied Forces in Europe.—M. G. Staton. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 130–134.) The radio relay system described comprises 7 terminal stations and 18 repeater stations, and provides 24 voice channels. The equipment is truck mounted and includes a 58-ft telescoping aerial tower. A f.m. system is used which makes interception difficult.

621.396.65.029.62 **851**

Design Considerations for V.H.F. Link Radio Equipment.—B. Wilson. (*G.E.C. Telecommun.*, Sept. 1953, No. 17, pp. 16–26.) General design of 54–330-Mc/s point-to-point R/T equipment is discussed. Both a.m. and f.m. equipments are considered.

621.396.712 : 621.396.61 **852**

The R.T.F. Transmitting Stations at Sélestat and Allouis L.W.—Gaillard. (See 886.)

621.396.712.029.62 **853**

Radio and Television in [Western] Germany.—(*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 497–499.) Operating frequency and power of the 90 or so v.h.f. stations are tabulated.

621.396.712.3 **854**

The Technical Equipment of the B.B.C. Swansea Studios.—W. J. Stentiford. (*B.B.C. Quart.*, Autumn 1952, Vol. 7, No. 3, pp. 169–173; *Proc. Instn Radio Engrs, Aust.*, Nov. 1953, Vol. 14, No. 11, pp. 270–273.)

621.396.7 **855**

Construction of a Mountain-Top Remote Base Station.—H. V. Church. (*Commun. Engng*, Sept./Oct. 1953, Vol. 13, No. 5, pp. 22–25..38.) An account of the 250-W station of the Central Vermont Public Service Corporation, installed on Pico Peak, altitude 4 000 ft. The station is remotely controlled by land-line from headquarters 12 miles away. Installation and maintenance problems peculiar to such a location are discussed in detail.

621.396.721 **856**

Two-Band Transmitter-Receiver.—G. P. Anderson. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, p. 37.) Correction to paper noted in 530 of February.

621.396.97 : 621.396.66 **857**

The Automatic Monitoring of Broadcast Programmes.—H. B. Rantzen, F. A. Peachey & C. Gunn-Russell. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 372–373.) Discussion on 269 of 1952.

SUBSIDIARY APPARATUS

621-526 **858**

A Nonlinear Servomechanism with Several Independent Variables.—D. Mitrovic. (*C. R. Acad. Sci., Paris*, 16th Nov. 1953, Vol. 237, No. 20, pp. 1209–1211.)

621.311.6 : 539.16 **859**

Radioactive Charging Effects with a Dielectric Medium.—P. Rappaport & E. G. Linder. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1110–1114.) The characteristics of a cell consisting of a Sr^{90}-Y^{90} β-ray source, a polystyrene dielectric separator and a collector made of carbon or metal, were investigated. Radioactive current and voltage sources similar to this cell are feasible. The arrangement offers a simple way of studying the effects of radiation on electrical processes in solids.

621.314.634 **860**

The Problem of Heating in the Selenium Rectifier.—W. Stiassny. (*Elektrotech. u. Maschinenb.*, 15th Sept.–15th Oct. 1953, Nos. 18–20, pp. 409–413, 437–441 & 455–

World Radio History

460.) Formulae for the calculation of heat losses are derived. Design for good efficiency and low-temperature rise is discussed in detail, with reference to the operational demands of various applications in power rectification. Typical characteristics curves are given.

621.314.65 **861**
Recent Developments in Ignitrons.—G. M. Zins. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 135–137.)

621.316.722 **862**
Stabilization Problems in Physics.—P. Goudal. (*Cah. Phys.*, Sept. 1953, No. 45, pp. 40–55.) A review of voltage, current, and magnetic-field regulators. The performances of various stabilizing valve circuits and primary regulators are compared, and the importance of good control of filament heating voltages is emphasized. Special problems of stabilization in nuclear physics are mentioned.

621.316.722 : 621.311.6 **863**
A Stabilized D.C. Supply Unit for Output Voltages of 0 to 300 V.—D. J. H. Admiraal. (*Electronic Applic. Bull.*, May 1953, Vol. 14, No. 5, pp. 61–71.) A circuit is described in which the whole of the output-voltage variation is available for controlling the amplifying valve, so that the gain is the same for any output voltage down to zero. The control valve is a pentode whose screen-grid voltage is stabilized by means of a stabilizer tube; the filaments of the amplifying valves, which are also fed from this source, have low consumption. Variation of the output voltage is < 2 mV for mains fluctuations up to 10%.

621.316.722 : 621.387 **864**
Relaxation Oscillations in Voltage-Regulator Tubes.—P. L. Edwards. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1756–1760.) Relaxation oscillations may occur if the regulator tube is shunted by a capacitor and the load line intersects the tube characteristic on the low-current side of the minimum. Methods of modifying the circuit to prevent these oscillations are indicated.

621.316.722.1 : 621.311.6 **865**
An Alternating-Current Stabilizer.—P. A. V. Thomas. (*Electronic Engng*, Dec. 1953, Vol. 25, No. 310, pp. 522–523.) A stabilizer for a valve-heater power supply uses a diode operating with low heater voltage as the error detector and a transductor as the control element. The output voltage can be maintained constant to within $\pm$ 1%.

621.373.4 **866**
Industrial Tube Generator for Low Frequencies.—H. Hertwig & F. N. Wissing. (*Electronic Applic. Bull.*, May 1953, Vol. 14, No. 5, pp. 72–75.) A detailed description is given of a three-phase valve generator suitable for supplying an asynchronous motor at frequencies from 1 to 2 kc/s.

TELEVISION AND PHOTOTELEGRAPHY

621.397.2(41) **867**
Television Service to Belfast.—T. Kilvington. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 130–133.) "Vision signals for the B.B.C. temporary television transmitter at Belfast are picked up direct from Kirk o' Shotts on 56·75 Mc/s at a receiving site on Black Mountain and passed on a carrier of 6·12 Mc/s over about a mile of coaxial cable to the temporary transmitter site in Glencairn, whence they are re-broadcast on a carrier of 45 Mc/s."

621.397.26 : 621.385.029.63 : 621.376.3 **868**
A 50-Watt F.M. Magnetron for Relay Service.—Kennedy. (See 904.)

621.397.5 : 535.623 **869**
The American Television Scene.—M. J. L. Pulling. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 13–15.) Impressions reported by a visiting British engineer, particularly of the colour-television demonstration staged on 15th October 1953.

621.397.5 : 535.623 **870**
Compatible Colour Television.—D. A. Bell. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, p. 31.) Sideband interference problems involved in using the N.T.S.C. colour-subcarrier system with the British television system are discussed; the narrower video-frequency band is the most serious difficulty.

621.397.5 : 535.623 **871**
The N.T.S.C. Color-Television Standards.—D. G. Fink. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 138–150.) The final N.T.S.C. compatible-colour signal specifications, presented in July 1953, are discussed in detail.

621.397.5 : 621.39.001.11 **872**
The Impact of Information Theory on Television.—D. A. Bell. (*J. Brit. Instn Radio Engrs*, Dec. 1953, Vol. 13, No. 12, pp. 590–591.) Discussion on 3731 of 1953.

621.397.5 (41) **873**
An Outline of the British Television System: Part 2 — Transmitting the Picture Waveform.—D. Wray. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 123–128.) The five-channel vestigial-sideband broadcasting system is outlined; operating frequency and power are tabulated for the ten stations. The transmitters are connected to the London studios by cable and radio links. Outside-broadcast material is transmitted over short distances either by coaxial or balanced-pair cable, portable radio links, or ordinary telephone pairs. Part 1: 271 of January.

621.397.611 : 621.375.232 **874**
Modified Preamplifier improves Movie Telecasts.—K. B. Benson. (*Electronics*, Dec. 1953, Vol. 26, No. 12, pp. 166–169.) A preamplifier circuit for use with an iconoscope combines a cascode arrangement with negative feedback. Advantages claimed are reduction of noise, of beam-current requirements and of spurious signals, and improvement in the rendering of the grey scale.

621.397.611.2 : 621.385.832 **875**
A Television Camera with an Image Iconoscope.—C. J. Seur. (*Commun. News*, Sept. 1953, Vol. 14, No. 1, pp. 29–34.) The equipment used in the Bussum studio for experimental transmissions is described.

621.397.621.2.001.4 **876**
Simple Linearity-Measuring Instrument.—Beauchamp. (See 811.)

621.397.7 **877**
Studio Equipment used for Television Broadcasting in the Netherlands.—J. M. Olthuis. (*Commun. News*, Sept. 1953, Vol. 14, No. 1, pp. 19–28.) Description of the equipment of the studios at Bussum, near Amsterdam.

621.397.7 : 534.86 **878**
The Sound Equipment in the Television Studio at Bussum.—A. Cramwinckel. (*Commun. News*, Sept. 1953, Vol. 14, No. 1, pp. 34–39.)

World Radio History

621.397.82 879

A Level Compensator for Telephotograph Systems.—T. A. Jones & W. A. Phelps. (*Elect. Engng, N.Y.*, Sept. 1953, Vol 72, No. 9, pp. 787–791.) The interference modulation in picture transmission via wide-band carrier equipment is effectively cancelled out by introducing an equal and opposite interference signal obtained by detecting a single-frequency pilot current transmitted simultaneously with the picture. Block diagrams and performance characteristics are given.

621.397.621.2 : 621.316.729 880

Flywheel Synchronization of Sawtooth Generators. (Book Review)—P. A. Neeteson. Publishers: Cleaver-Hume Press, London, 156 pp., 21s. (*Wireless Engr*, Jan. 1954, Vol. 31, No. 1, pp. 27–28.) " . . . a necessary book for the designer."

TRANSMISSION

621.376.223 881

Balanced Crystal-Diode Modulator.—W. F. Byers. (*Radio & Telev. News, Radio-Electronic Engng Section*, Sept. 1953, Vol. 50, No. 3, pp. 10–11, 27.) Description of the low-power Si-diode modulator Type 1000-P7, giving linear operation over the range 0–20 Mc/s at carrier frequencies from 60 Mc/s to 2·5 kMc/s. Circuit diagram and performance figures are given.

621.396.61.029.58 : 621.396.65 882

Single-Sideband Multi-Channel Operation of Short-Wave Point-to-Point Radio Links: Part 4(a)—An Independent-Sideband High-Power Short-Wave Transmitter—The Radio and Power Units.—H. E. Sturgess & F. W. Newson. (*P.O. elect. Engrs' J.*, Oct. 1953, Vol. 46, Part 3, pp. 140–143.) The transmitter can provide peak power up to 70 kW in the frequency range 4–22 Mc/s. By using the two-channel drive unit described in part 2 (2175 of 1953 (Owen & Ewen)) the transmitter can also be used for d.s.b. telephony and c.w. and m.c.w. telegraphy.

621.396.61.029.62 883

A New V.H.F. Transmitter for Frequency Modulation.—W. Grimbaldeston. (*G.E.C. Telecommun.*, Sept. 1953, No. 17, pp. 27–33.) Description of the BRT-108 250-W transmitter, for 71·5–100 Mc/s. Ph.m. corrected to f.m. over the required audio range is used. The nominal frequency deviation is ±15 kc/s for 0·5 mV across the 15-Ω input, at 1 kc/s modulation frequency.

621.396.662 : 621.316.7 884

Automatic Control System with Provision for Scanning and Memory.—N. H. Young. (*Elect. Engng, N.Y.*, Sept. 1953, Vol. 72, No. 9, pp. 782–784.) The control element (e.g. a tuning capacitor) is scanned through its entire range of adjustment and the input voltage is fed, via a diode, to the 'memory' capacitor, causing it to charge up to the maximum peak value. On re-scanning, the input voltage is compared with this peak value; the control element is stopped when they are equal. A simplified circuit diagram is given, and a radio transmitter embodying the system is briefly described.

621.396.665 885

Circuits for Limiting Peak Voltages.—E. G. Beard. (*Philips tech. Commun., Aust.*, 1953, No. 3, pp. 11–15.) A system of amplified a.g.c. for preventing overmodulation of a transmitter is described. The peak signal voltages trigger a quiescent 1-Mc/s oscillator which then oscillates in a series of pulses. The length of the pulse sequence is a function of the signal amplitude. The rectified and integrated pulses are used for the a.g.c. bias.

621.396.712 : 621.396.61 886

The R.T.F. Transmitting Stations at Sélestat and Allouis L.W.—A. Gaillard. (*Onde élect.*, Aug./Sept. 1953, Vol. 33, Nos. 317/318, pp. 489–496.) The long-wave transmitter at Allouis, which was destroyed in 1944, was re-started in October 1952. The power is 250 kW; it is planned to add a second transmitter to bring the total power up to 450 kW. Anode modulation is used, with two Type-E3056 valves in push-pull in the r.f. stage. The aerial is a folded unipole designed to handle a bandwidth 12·4% of the carrier frequency; its total height is 308 m. The new Sélestat station, intended to serve the whole of Alsace, also came into full operation in October 1952. It has two 150-kW transmitters, each comprising two units. There are two widely spaced aerials, one 115 m and the other 90 m high. The heat developed at the anodes of the power valves is recovered and used for heating the buildings. See also 1735 of 1952.

VALVES AND THERMIONICS

621.314.632 887

Post-Injection Barrier Electromotive Force of *p-n* Junctions.—B. R. Gossick. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1012–1013.) By injecting carriers across a *p-n* junction with a high-back-voltage point-contact diode in series, the post-injection barrier e.m.f. may be observed under approximately open-circuit conditions. From measurements using a CK708 diode, the calculated e.m.f. is ~ 0·2 V at room temperature.

621.314.632 : 546.289 888

Effect of Transit Time on Ge-Rectifier Behavior.—R. Bray & B. R. Gossick. (*Phys. Rev.*, 15th Aug. 1953, Vol. 91, No. 4, pp. 1011–1012.) The forward characteristics of Ge point-contact rectifiers were measured using 0·4-μs pulses. Resistance was very much higher at the beginning of the pulse than at the end, when it reached the d.c. value. Thus transit times <0·4 μs are involved. In *p-n*-junction rectifiers, the resistance takes longer to change, and is still much higher than the d.c. value at the end of a 3·6-μs pulse.

621.314.632 : 546.289 889

The Manufacturing and Testing of Germanium Rectifiers.—C. Peters & H. Strong. (*G.E.C. Telecommun.*, Sept. 1953, No. 17, pp. 34–39.) An illustrated account dealing with point-contact Ge diodes.

621.314.632 : 621.376.233 890

Crystal-Mixer Design at Frequencies from 20 000 to 60 000 Mc/s.—C. R. Ditchfield. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 365–371.) Crystal valves designed during the war are reviewed. A new design of plug-in waveguide type is described and some performance figures are given. With a minor modification to the holder, this type can be used as a harmonic generator.

621.314.7 891

A Germanium *N-P-N* Alloy Junction Transistor.—D. A. Jenny. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1728–1734.) The transistor discussed is the counterpart of the *p-n-p* type described by Law et al. (876 of 1953). It is made by fusing Pb-Sb alloy into both faces of a thin wafer of *p*-type single-crystal Ge. Compared with the *p-n-p* type, the penetration of the alloy is more uniform, giving flatter junctions and better control of junction spacing. Test figures for a typical lot of 100 units are given; the best values obtained are 45 db for the power gain, 0·997 for α and 3 db for the 1-kc/s noise

World Radio History

factor. The h.f. performance is better than that of the *p-n-p* type, but the improvement is not so great as would be expected from the electron/hole mobility ratio.

621.314.7 **892**

Home-Made Transistors.—P. B. Helsdon. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 20–23.) Practical details are given for converting selected Ge diodes into point-contact transistors.

621.314.7 **893**

The Surface-Barrier Transistor: Part 1 — Principles of the Surface-Barrier Transistor.—W. E. Bradley. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1702–1706.) The 'surface-barrier' transistor comprises a plate of *n*-type single-crystal Ge with the thickness at a central region reduced to a few microns, and emitter and collector electrodes plated respectively on to the two faces at the thinned region. A method of production is used which permits accurate control of the geometry. An explanation is given of the hole-emission, conduction and collection mechanisms involved in the operation; this depends on the formation of a layer about 0·0001 in. thick just below the Ge surface, within which there are practically no free charge carriers. Efficient operation at frequencies > 60 Mc/s has been achieved with a supply voltage of 3 V.

621.314.7 **894**

The Surface-Barrier Transistor: Part 4 — On the High-Frequency Performance of Transistors.—R. Kansas. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1712–1714.) A theoretical determination of the α-cut-off frequency for the surface-barrier transistor is given, based on analysis presented by Steele (881 of 1953) for junction transistors. Values found from the theory are compared with experimental values. The effect of nonuniformity of the thickness of the Ge is demonstrated. Part 3: 692 above.

621.314.7 : 537.311.33 **895**

The Surface-Barrier Transistor: Part 5 — The Properties of Metal-to-Semiconductor Contacts.—R. F. Schwarz & J. F. Walsh. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1715–1720.) An investigation is made of the properties of the plated In-Ge junctions formed by the technique used in the production of the surface-barrier transistor (see 896 below). Measured I/V characteristics are only slightly different from those for alloyed junctions. The shape and capacitance of the barrier are discussed; from a comparison of measured capacitance values with theoretically derived values it is inferred that the effective area of the barrier is of the same order of magnitude as the actual area of the plated electrode. Expressions are derived for the hole and electron currents across the barrier, and it is shown that enhanced hole current is obtained in the transistor as a result of the relatively small distance between the emitter and collector electrodes. Part 4: 894 above.

621.314.7.002.2 **896**

The Surface-Barrier Transistor: Part 2 — Electrochemical Techniques for Fabrication of Surface-Barrier Transistors.—J. W. Tiley & R. A. Williams. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1706–1708.) Details are given of the method used to reduce the thickness of the Ge plate (see 893 above). Two glass nozzles of diameter about 0·005 in. are mounted so as to direct jets of electrolyte on to the two faces of the plate, the latter being connected as anode. An even etch is obtained. The influence of illumination and of the high resistivity of the surface barriers on the passage of the etching current is discussed. When the etching is completed, the polarity of the system is reversed and the transistor electrodes are plated on using the same arrangement of equipment. Experiments indicate that In is a suitable metal for the electrodes. In typical units the diameter of the etched pit is 0·015 in., that of the emitter is 0·003 in., and that of the collector 0·006 in. The unit is provided with a Ni base tab by which it is mounted on a glass stem. Part 1: 893 above.

621.38.002.2 : 53 **897**

Physics in the Electronic Valve Industry.—J. Thomson. (*Brit. J. appl. Phys.*, Sept. 1953, Vol. 4, No. 9, pp. 262–267.) The importance of physics in the development and manufacturing stages of production of various electronic devices is indicated.

621.385 : 621.372.57 **898**

Starvation Circuits and their Limitations.—Erdle. (See 680.)

621.385 : 621.396.662 **899**

Tuning-Indicator Valves.—F. Malsch. (*Elektrotech. Z., Edn A*, 1st Sept. 1953, Vol. 74, No. 17, pp. 497–500.) Description of the construction and operation of various types of indicator valve, including some relatively little used ones.

621.385 : 681.142 **900**

The Univac Tube Program.—Hinkelman & Kraus. (See 647.)

621.385.029.6 **901**

Some Recent Work in France on New Types of Valves for the Highest Radio Frequencies.—R. Warnecke & P. Guénard. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 351–362.) The valves reviewed include reflex klystrons, multicavity klystrons, velocity-modulation valves with distributed buncher, travelling-wave valves, magnetrons, magnetron-type travelling-wave valves, and backward-wave valves (called carcinotrons). Theory is given, design aspects are discussed, and some performance figures are presented. References to papers dealing with these valves in greater detail are included.

621.385.029.6 : 621.372.2 **902**

Analysis of a Transmission-Line Type of Thermionic-Amplifier Valve.—I. A. D. Lewis. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 16–24.) Analysis is presented for a line comprising two helices in proximity to an earthed straight conductor. Two waves in each direction, with different phase velocities, can co-exist. The design of a valve is discussed with a cylindrical cathode and coaxial helical grid and anode. Waves in the slower mode, in which anode and grid voltages are out of phase, are amplified according to an exponential law; waves in the faster mode, in which anode and grid voltages are in phase, are attenuated by a similar amount. For perfect matching at the ends of the line, the two helices must be wound in opposite senses and the coefficients of inductive and capacitive coupling must be equal. With a valve of this type a balanced output could be obtained with an unbalanced input.

621.385.029.63/.64 **903**

Electron Flow through Small Tubes with Magnetic Focusing.—J. L. Stewart. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1236–1240.) A calculation is made of the beam current flowing through a narrow tube or between a pair of parallel plates, taking account of the helical electron motion due to the magnetic focusing. The results are presented graphically. Expressions are also given for the current intercepted and for an equivalent beam conductance relating the power

World Radio History

associated with the rotational motion of the beam to the intensity of an applied transverse electric field. The theory is applicable to travelling-wave valves.

621.385.029.63 : 621.376.3 : 621.397.26 **904**

A 50-Watt F.M. Magnetron for Relay Service.—D. P. Kennedy. (*Tele-Tech*, Aug. 1953, Vol. 12, No. 8, pp. 66–68.) Outline descriptions are given of the QK-174C magnetron oscillator, which is continuously tunable over the frequency range 1·99–2.11 kMc/s, and of a television relay transmitter incorporating it. The associated wide-band f.m. receiver is also briefly described.

621.385.029.64 **905**

Low-Noise Traveling-Wave Tubes for X-Band.—D. A. Watkins. (*Proc. Inst. Radio Engrs*, Dec. 1953, Vol. 41, No. 12, pp. 1741–1746.) Tests on valves using velocity jumps for noise reduction (1470 of 1952) show that best results are obtained with a single-jump arrangement in which the electrodes are shaped so as to make the transition from the low-voltage to the high-voltage space relatively gradual. A valve with a noise figure of 11·3 db and a gain of 18 db at 9 kMc/s is described The variation of noise figure with magnetic field, operating voltage and cathode temperature is shown graphically.

621.385.032.216 **906**

The Life of Oxide Cathodes in Modern Receiving Valves.—G. H. Metson, S. Wagener, M. F. Holmes & M. R. Child. (*Proc. Instn elect. Engrs*, Part III, Nov. 1953, Vol. 100, No. 68, pp. 371–372.) Discussion on 1781 of 1952.

621.385.032.216 : 621.317.332 **907**

The Dependence of Mutual Conductance on Frequency of Aged Oxide-Cathode Valves and its Influence on their Transient Response.—J. R. Tillman, J. Butterworth & R. E. Warren. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 8–15.) Full paper. See 2838 of 1953.

621.385.1 **908**

Valve Codes.—M. H. N. Potok. (*Wireless World*, Jan. 1954, Vol. 60, No. 1, pp. 38–40.) An examination of the possibility of devising a method of designation which will serve not only to distinguish valves which are not interchangeable but also to give information about the properties of the valve designated.

621.385.2 **909**

The Space-Charge Smoothing Factor: Part 3.—C. S. Bull. (*Proc. Instn elect. Engrs*, Part IV, Oct. 1953, Vol. 100, No. 5, pp. 47–50.) In a previous paper (2383 of 1950), thirty partial differential coefficients were enumerated which together express the characteristics of a diode. A study of the effect of fluctuations on one of these coefficients brings to light a serious error in all prior work on the subject. As a result, it may be assumed that the total emission fluctuates according to the law derived by Schottky in 1918, and estimates of the fluctuations can hence be obtained in closer agreement with values observed experimentally. Part 2: 291 of 1953.

621.385.3.029.63 **910**

A Disc-Seal Triode as a U.H.F. Amplifier.—S. C. Peek. (*Sylvania Technologist*, Oct. 1953, Vol. 6, No. 4, pp. 81–85.) The construction of the Type-6BA4 planar triode is described, and the results of performance tests in a 450–900-Mc/s grounded-grid coaxial amplifier are given. At 890 Mc/s a power gain of 14 db and a noise figure of 10 db were obtained.

621.385.83 **911**

Spatially Alternating Magnetic Fields for Focusing Low-Voltage Electron Beams.—J. R. Pierce. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, p. 1247.) A note referring to the work of Courant et al. (1454 of 1953). The solution of the equations of motion of an electron in axially symmetrical, converging, periodic magnetic fields shows that dense beams can be stable in such fields. Periodic focusing is discussed briefly.

621.385.83 : [621.317.329 + 517.944 **912**

Electrostatic Potential Plotting for Use in Electron-Optical Systems.—Kuo-Chu Ho & R. J. Moon. (*J. appl. Phys.*, Sept. 1953, Vol. 24, No. 9, pp. 1186–1193.) A noniterative numerical method is developed for solving a partial differential equation, the boundary conditions of which are not known over the entire closed boundary. This method is used to calculate the shapes of beam-forming electrodes for a rectilinear flow. Complete agreement is obtained with Pierce's experimental results (4275 of 1940) and with the results of electrolyte-trough determinations.

621.385.832 : 621.317.32 **913**

Measurement of Voltage using a Simple Electron-Beam Valve.—Lieb. (See 798.)

621.385.832 : 621.318.572 **914**

The E1T Decade Counter Tube.—(*Electronic Applic. Bull.*, May 1953, Vol. 14, No. 5, pp. 71, 76.) Corrections and addendum to paper noted in 603 of February.

621.385.832.002.2 **915**

The Production of Emiscope Cathode-Ray Tube Gun-Assemblies.—(*Machinery, Lond.*, 18th Sept. & 23rd Oct. 1953, Vol. 83, Nos. 2131 & 2136, pp. 555–563 & 795–800.)

621.385.832.002.2 : 681.142 **916**

Cementing Metal Screens to Cathode Ray Tubes.—R. W. Holmes. (*Mater. & Meth.*, Sept. 1953, Vol. 38, No. 3, pp. 184, 186.) The method described was used for fixing fine mesh screens externally to the screens of c.r.-tube storage units for the AVIDAC digital computer.

621.385.832.012 **917**

Experimental Determination of the Characteristic-Curve Index in Cathode Ray Tubes.—E. Gundert. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 340–341.) The cathode current J_k in a triode gun is related to the control grid voltage U_g by the equation $J_k = K(U_g - U_{sp})^n$ where U_{sp} is the value of U_g for $J_k = 0$. Logarithmic plotting presupposes a knowledge of U_{sp}, which, owing to the Maxwell electron velocity distribution, is not easily determined. A formula is derived from which n can be calculated by substituting the values of U_g corresponding to three values of J_k in geometrical progression. For cathode currents up to about 100 μA, $n \approx 2{\cdot}5$.

621.387.032.212 : 621.396.665 **918**

Gas-Discharge Tubes for Control of Microwave Attenuation.—D. H. Pringle & E. J. Whitmore. (*J. sci. Instrum.*, Sept. 1953, Vol. 30, No. 9, pp. 320–323.) Details are given of the construction and operation of cold-cathode tubes as attenuators for the 3-cm waveband. Operation depends on the interaction between the microwave field and the electron gas supported by the discharge plasma. Construction is based on that of conventional t.r. switches; a high-Q narrow-band type and a low-Q wide-band type are described. Applications to a.g.c. and modulator circuits are discussed.

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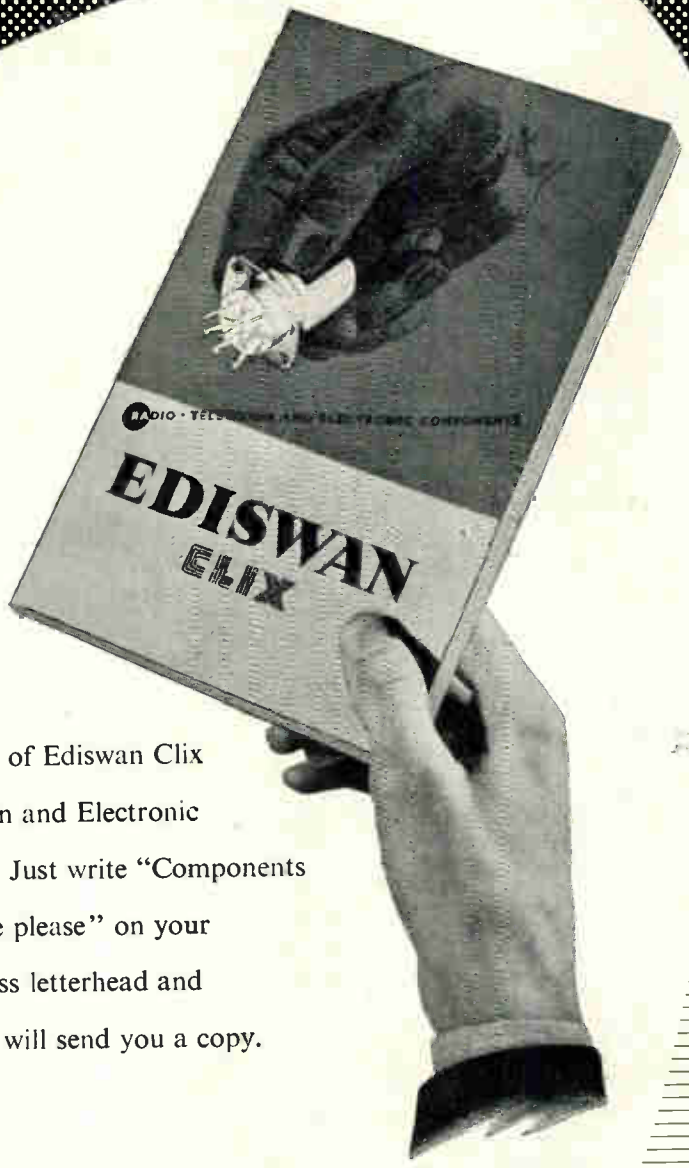

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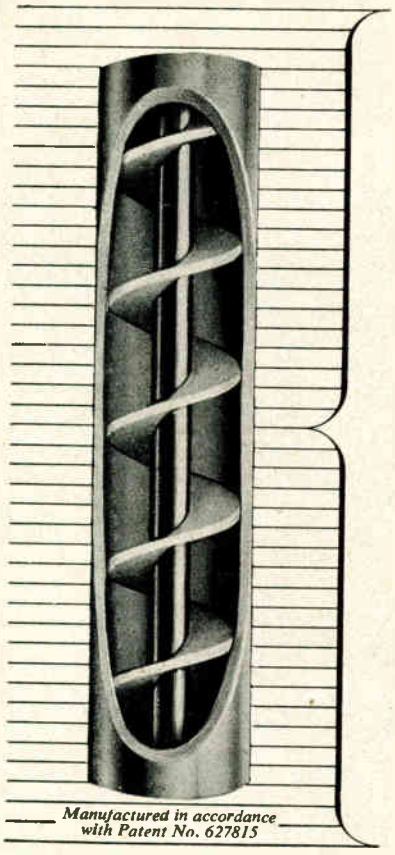

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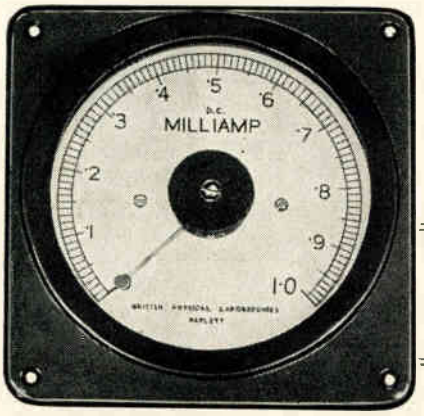

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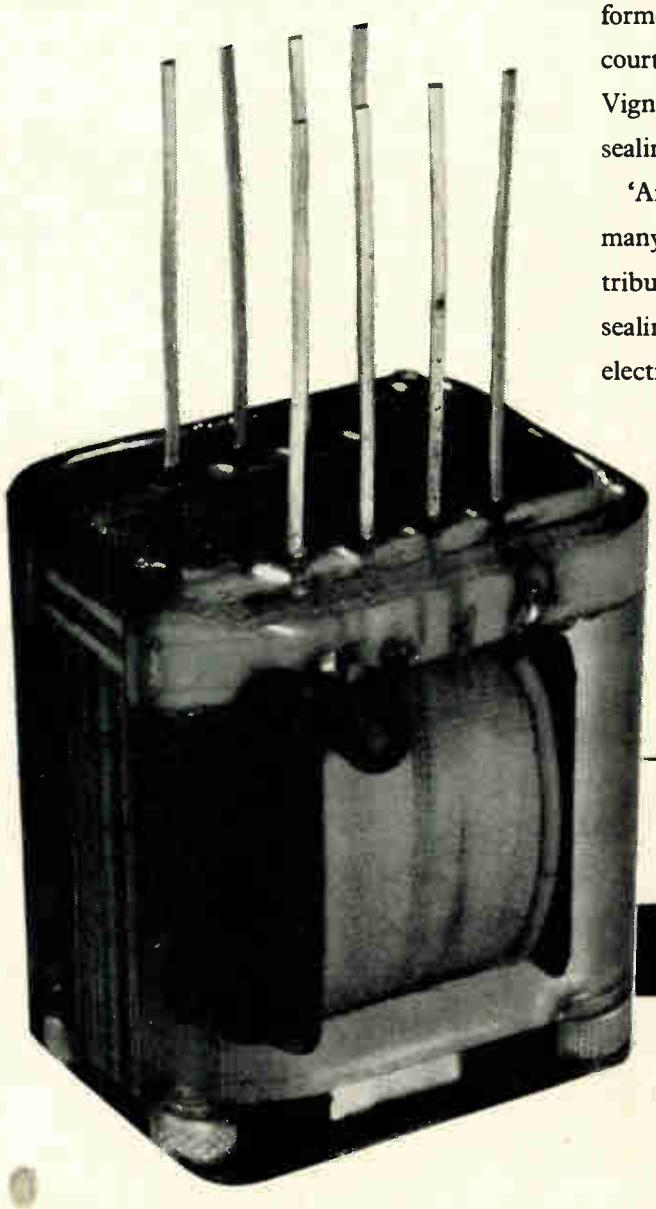

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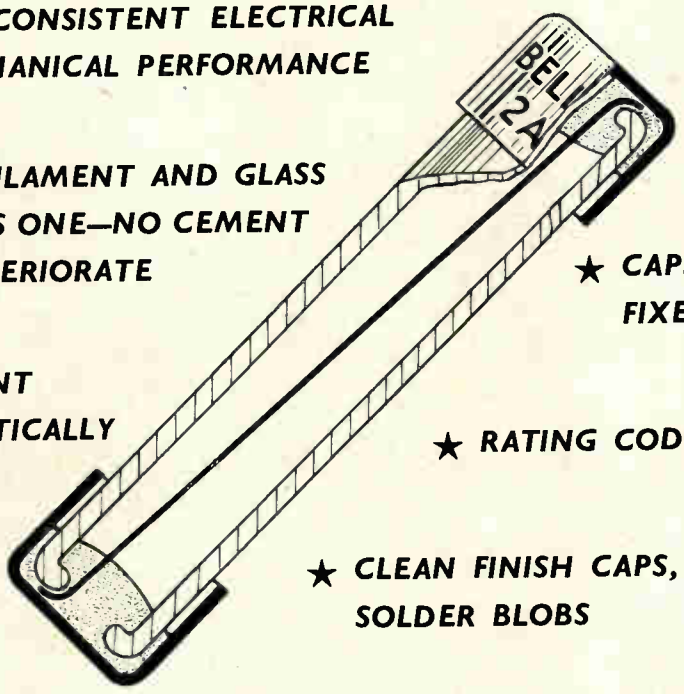

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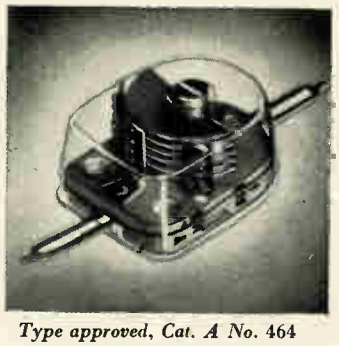

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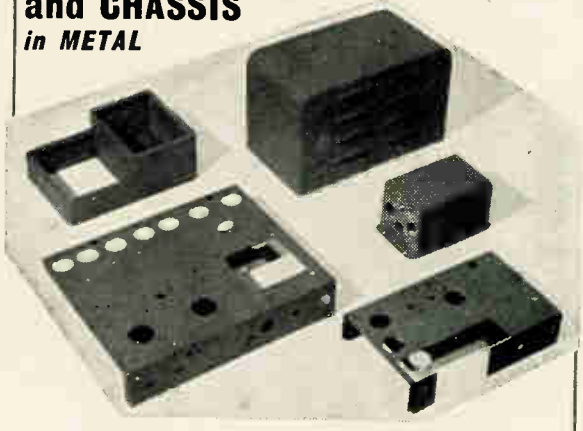

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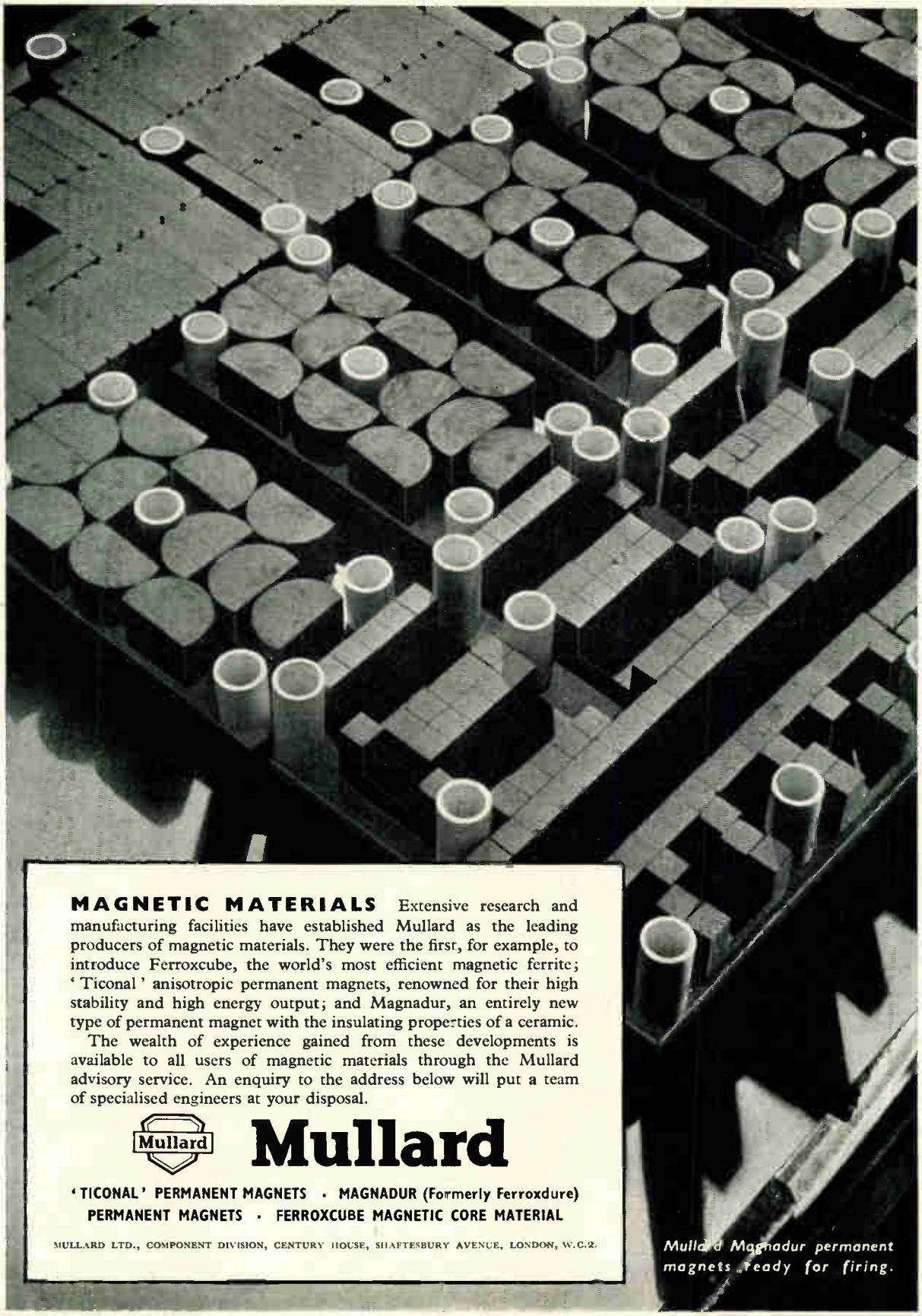

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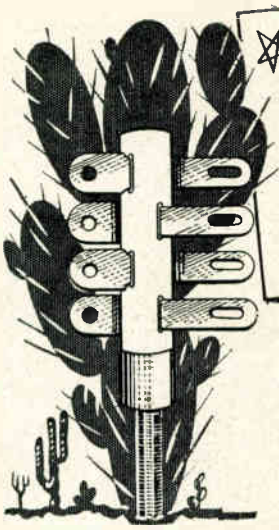

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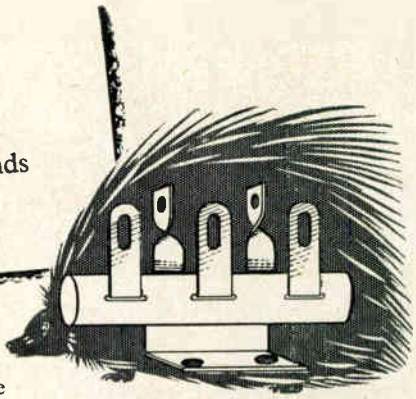

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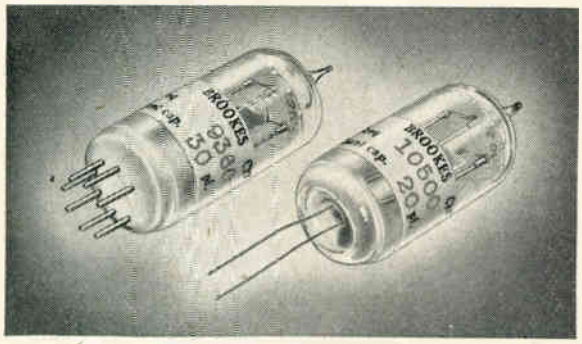

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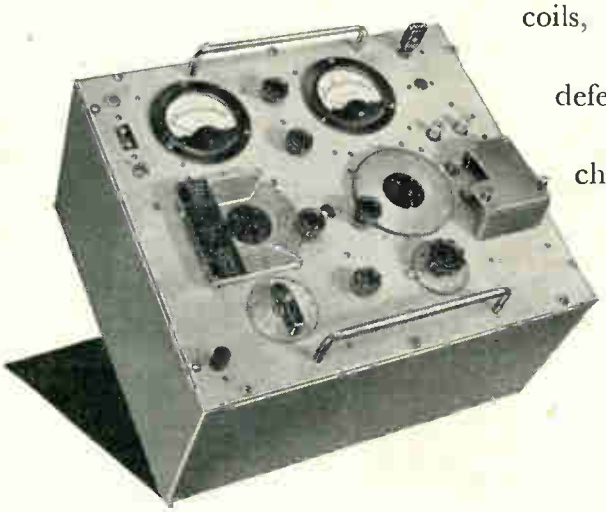

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Index to Advertisers

	PAGE
Advance Components, Ltd.	11
Aero Research, Ltd.	19
Airmec, Ltd.	20
Amplex Appliances (Kent), Ltd.	24
Appointments	26, 27
Belfast College of Technology	26
Belling & Lee, Ltd.	21
British Insulated Callender's Cables, Ltd.	10
British Physical Laboratories	18
Brookes Crystals, Ltd.	24
Bullers, Ltd.	Cover ii
Chase Products (Engineering), Ltd.	22
Edison Swan Electric Co., Ltd., The	17
Ekco Electronics, Ltd.	13
Electronic Components.	22
Erie Resistor, Ltd.	9
Ferranti, Ltd.	6
Foyle, W. & G., Ltd.	26
Griffiths, Gilbart, Lloyd & Co., Ltd.	12
Hunt, A. H. (Capacitors), Ltd.	Cover iv
Lyons, Claude, Ltd.	1
Marconi Instruments, Ltd.	25
McMurdo Instrument Co., Ltd.	12
Methuen & Co., Ltd.	24
Muirhead & Co., Ltd.	8
Mullard, Ltd.	2, 16, 23
Murex, Ltd.	8
Oxley Developments Co., Ltd.	22
Pitman, Sir Isaac & Sons, Ltd.	12, 26
R.E.M.E.	26
Salford Electrical Instruments, Ltd.	20
Standard Telephones & Cables, Ltd.	4
Sullivan, H. W., Ltd.	14
Telegraph Condenser Co., Ltd., The	Cover iii
Telegraph Construction & Maintenance Co., Ltd., The	18
Telephone Mfg. Co., Ltd.	7
Unbrako Socket Screw Co., Ltd.	3
United Insulator Co., Ltd.	24
Wayne Kerr Laboratories, Ltd., The	5

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World Radio History

INDEX

Vol 30 Wireless Engineer 1953

	MONTH	PAGE
ABSTRACTS AND REFERENCES (*see Special Index*)		
Aerial, Non-Resonant Sloping-V, J. S. Hall	Sept.	223
—— Radiation Patterns, T. T. Ling	Aug.	192
Aerials and Arrays, Mutual Radiation Resistance of, (*Correspondence*)	Jan.	24
——, Cylindrical, (*Correspondence*)	Jan.	24
——: Folded Dipoles (*Editorial*)	Mar.	51
——: Microwave Angle Scanner, J. Brown	Oct.	250
——: Power Gain of Curtain Arrays, P. Hammond	May	108
——, Television, G. W. Luscombe	Apr.	82
Amplifiers, Distributed, B. Murphy	Feb.	39
——, Noise Factor of Conventional V.H.F., N. Houlding	Nov. 281, Dec.	299
——: RC or Direct-Coupled Power Stage, E. F. Good	Mar.	54
Analysis, Initial Conditions in Transient, L. Tasny-Tschiassny	Feb.	28
——, Units and Rationalization, Dimensional, (*Editorial*)	Sept.	209
Angwin, Col. Sir A. Stanley	Mar.	72
Anode-Follower Derivatives, A. W. Keen (*Correspondence*)	Jan. 5, Feb. 48, Apr. 97, May	123
Automatic Ionospheric Height Recorder, C. Clarke and E. D. R. Shearman	Sept.	211
BAND-PASS FILTERS, Fuad Surial Atiya	Dec.	307
Bandwidth Limitation of Junction Transistors (*Correspondence*)	Oct.	261
BOOKS AND TECHNICAL PUBLICATIONS:		
A.R.R.L. Handbook 1953	July	183
Advanced Five-Figure Mathematical Tables, C. Attwood (*Review*)	Apr.	99
Amateur's Guide to Valve Selection, Mullard	Feb.	50
Analysis of A.C. Circuits, W. R. Le Page (*Review*)	Apr.	98
Applied Electronics Annual 1952, Edited by R. E. Blaise	Mar.	74
Basic Electronic Test Instruments, Rufus P. Turner	Apr.	100
Bidrag til Teorien for Antennesystemer med hel eller delvis Rotationssymmetri, H. Lottrup Knudsen	July	183
BRITISH STANDARDS:		
Dimensions of Circular Cone Diaphragm Loudspeakers	Apr.	100
Lateral-Cut Gramophone Records and Direct Recordings	Apr.	100
Measurement of Frequency Variation in Sound Recording and Reproduction	Oct.	262
Radio Interference Suppression for Motor Vehicles and Internal Combustion Engines	Apr.	100
Thermosetting Synthetic-resin Bonded-paper Round Tubes for use at Radio Frequencies	June	142
Cabma Register, 1953	Sept.	231
Cathode-Ray Oscillograph in Industry (4th Edition), W. Wilson	July	183
Characteristics of the Ionosphere observed in Gt. Britain 1930-1946, Radio Research Report	June	142
Copper in Instrumentation	Dec.	319
Currents and Fields in Electrical Engineering, Prof. H. E. M. Barlow	Jan.	26
Dipole Moments, R. J. W. Le Fevre	Nov.	291
Dry Electrolytic Capacitors, U.S. Mutual Security Agency	July	183
Einführung in die Mikrowellen-Elektronik—Part 1, Dr. Werner Kleen (*Review*)	June	159
Electrical Units (With Special Reference to the M.K.S. System), Eric Bradshaw (*Review*)	Apr.	98
Electron Optics, O. Klemperer (*Review*)	Dec.	318
Electronic Measurements, F. E. Terman and J. M. Pettit (*Review*)	Jan.	25
Electronics for Communication Engineers, John Markus and Vin Zeluff	Feb.	50
Electronique Générale, A. Blanc-Lapierre, R. Goudet and P. Lapostolle	Nov.	291

BOOKS—*continued*	MONTH	PAGE
Elektroakustik: Music und Sprache, Dr. F. C. Sai (*Review*)	Apr.	99
Elements of Radio Engineering, H. I. F. Peel	Mar.	74
Essentials of Microwaves, Robert B. Muchmore	June	160
Examples in Electrical Calculations, Admiralty (*Review*)	Jan.	25
Faster than Thought, Edited by B. V. Bowden, (*Review*)	Dec.	318
Ferroxcube	Dec.	319
Filter Design Data for Communication Engineers, J. H. Mole (*Review*)	May	129
Filtres Electriques (3rd Edition), Pierre David	Apr.	100
Fundamental Processes of Electrical Contact Phenomena, F. Llewellyn Jones, Radio Research Special Report No. 24	Oct.	261
Fundamentals of Engineering Electronics (2nd Edition) William G. Dow	July	183
Fundamentals of Thermometry, J. A. Hall	July	184
Guide to Broadcasting Stations (7th Edition)	Oct.	262
Information Theory and its Engineering Applications, D. A. Bell (*Review*)	July	182
Introduction to Valves, R. W. Hallows and H. K. Milward	Sept.	231
Ionosphäre, Dr. K. Rawer (*Review*)	Mar.	74
Journal of the Audio Engineering Society	Sept.	234
Laplace-Transformation und ihre Anwendung, Paul Funk, Hans Sagan and Franz Selig	Dec.	319
Lewis's Medical, Scientific and Technical Lending Library Catalogue. Supplement 1950-52	Aug.	208
Lignes à Retard et leur Utilisation, Gaston Potier	Dec.	319
M.K.S. System of Units, T. McGreevy (*Review*)	Dec.	317
Magnetic Circuit, A. E. De Barr	July	183
Measurement of Linear and Non-Linear Distortion in Electro-Dynamic Loudspeakers, Fritz Ingerslev	July	183
Measurement of Radio Interference in the Frequency Range 0·15 to 30 Mc/s. A Mains Isolating Unit, J. Miedzinski and S. F. Pearce	Dec.	319
Measurement of Radio Interference in the Frequency Range 0·15 to 30 Mc/s. A Portable Measuring Set, S. F. Pearce and D. C. G. Smith	Dec.	319
Measurements of Atmospheric Noise at High Frequencies 1945-1951, F. Horner	Dec.	319
Mikrowellenbandfilter im Hohlleiter, Dr. F. S. Atiya (*Review*)	May	130
NATIONAL BUREAU OF STANDARDS:		
Construction and Application of Conformal Maps	Apr.	100
Electrodeposition Research	Dec.	320
Introduction to the Theory of Stochastic Processes Depending on a Continuous Parameter, Henry B. Mann	June	142
Mass Spectroscopy in Physics Research	June	142
Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water	June	142
Radio Frequency Power Measurements, R. A. Schrack	June	142
Reference Data for Orienting Quartz Plates by X-Ray Diffraction, Catherine Barclay and Leland T. Sogu	Dec.	320
Supplementary List of Publications, 1st July 1947–30th June 1952	Apr.	100
Table of Dielectric Constants and Electric Dipole Moments of Substances in the Gaseous State. Arthur A. Marryott and Floyd Buckley	Dec.	320
Tables of Bessel Functions $Y_0(x)$, $Y_1(x)$, $K_0(x)$, $K_1(x)$, $0 < x < 1$	Apr.	100
Tables of Normal Probability Functions	Dec.	320
Osram Valve Manual, Part 2	Dec.	319
Permanent Effect of Water on Varnished Coils, H. R. Heap	Dec.	319

World Radio History

BOOKS—*continued*

	MONTH	PAGE
Permanent Magnets, Mullard	Oct.	262
Permanent Magnets, Permanent Magnet Assn.	Aug.	208
Physical Formulae, T. S. E. Thomas	Apr.	100
Practical Thermometry, J. A. Hall	July	184
Preferred Valves, S.I.M.A. List	Sept.	234
Principles of Electronics, H. Buckingham and E. M. Price	Nov.	291
Principles of Radar (3rd Edition), M.I.T.	June	160
Proceedings of the Western Computer Conference, I.R.E. America	Dec.	319
R.C.A. Technical Papers (1952) Index Vol. III(b)	Aug.	208
Radio and Radar Technique, Dr. A. T. Starr (*Review*)	July	182
Radio and Television Manufacturing	Jan.	26
Radio Antenna Engineering, Edmund A. Laport	July	183
Radio Designers' Handbook, F. Langford-Smith	June	160
Radio Engineering (2nd Edition), Vols. I and 2, E. K. Sandeman	Nov.	291
Radio Engineers' Servicing Manual, Edited by E. Molloy	Feb.	50
Radio Research 1952	Oct.	262
Radio Spectrum Conservation	Feb.	50
Radio Upkeep and Repairs (7th Edition), Alfred T. Witts	July	183
Redresseurs en Simple Alternance, J. Lecorguillier	Dec.	319
Régimes Transitoires dans les Réseaux Electriques, Paul Poincelot	Dec.	319
Remote Control by Radio, A. H. Bruinsma	Apr.	100
Resonant Cavity Magnetron, R. S. H. Boulding	Feb.	50
Schweizerisches Bezugsquellen-Lexikon für Electro-Industrie und-Handel 1952/56 (2nd Edition)	Nov.	291
Selected Problems in the Preparation, Properties and Application of Materials for Radio Purposes, D.S.I.R.	Apr.	100
Signal, Noise and Resolution in Nuclear Counter Amplifiers, A. B. Gillespie (*Review*)	Apr.	99
Small Transformers and Inductors, K. A. MacFadyen (*Review*)	Nov.	291
Soft Magnetic Materials used in Industry, A. E. De Barr	July	183
Some Researches on High Frequency Phenomena and Electrical Direct Heating, Edited by Y. Asami	Apr.	100
Synchronization of Reflex Oscillators, Aly H. Abdel Dayem	Nov.	291
Taschenbuch für Elektrotechniker, Book I: Fundamentals, Dr. Ing. Franz Moeller	Feb.	50
Telefonia a Grande Distanza, Vol. 2, Dott.Ing. Renzo Possenti	Feb.	50
Television and Radio Repairing, John Markus	Nov.	291
Television Engineering, S. W. Amos, D. C. Birkinshaw and J. L. Bliss	Sept.	231
Television Engineers' Servicing Manual, Edited by E. Molloy	Feb.	50
Television Receiver Design: I.F. Stages, A. G. W. Uitjens (*Review*)	June	159
Temperature and Humidity Gradients in the First 100 m over South-East England, A. C. Best, E. Knighting, R. H. Pedlow and K. Stormonth	Apr.	100
Thermionic Vacuum Tubes (6th Edition), W. H. Aldous and Sir Edward Appleton	Apr.	100
Théorie des Circuits Impulsionnels, H. Borg	Dec.	319
Transmission Téléphonique—Théorie des Lignes, R. Croze and L. Simon	Apr.	100
Use of Radar at Sea, Edited by Capt. F. J. Wylie	Mar.	74
Vacuum-Tube Oscillators, William A. Edson, (*Review*)	July	183
Wireless & Electrical Trader Year Book (24th Edition)	July	183
Wireless World Diary 1954	Nov.	291
Bridge with Variable-Ratio Arms, High-Frequency, J. E. Houldin and G. T. Thompson	Feb.	32
Brit. I.R.E. President	Oct.	262
British Instrument Industries Exhibition	July	184
British Standards Institution, Change of Address	Sept.	234

CATHODE-FOLLOWER Feedback Circuits, RC., S. C. Dunn — Jan. 10
Cathode-Follower Operation (*Correspondence*) — Feb. 49
Circuit Diagrams (*Editorial*) — Jan. 1
"Coding, Ideal", versus "Redundancy" (*Correspondence*) — Mar. 73

CORRESPONDENCE:

	MONTH	PAGE
Anode Follower, M. G. Scroggie, Feb. 48; A. W. Keen, Apr. 97; Geo. L. Connon	May	123
Bandwidth Limitation of Junction Transistors, A. J. W. M. van Overbeek and F. H. Stieljes	Oct.	261
Cathode-Follower Operation, H. H. Adelaar	Feb.	49
Current Noise in Semi-Conductors, D. A. Bell	Jan.	23
Cylindrical Aerials, Ronold W. P. King	Jan.	24
Formulae for Ladder Filters, A. T. Starr, Mar. 73; E. Green	May	123
Harmonic Distortion and Negative Feedback, Frank G. Kerr, Sept. 232, Nov. 292; S. Uminski, R. O. Rowlands, Sept. 233, Oct. 261; G. F. Nicholson	Nov.	291
"Ideal Coding" versus "Redundancy", D. A. Bell	Mar.	73
Mutual Radiation Resistance of Aerials and Arrays, L. Lewin	Jan.	24
Networks with Maximally-Flat Delay, Kiyasu-Zen'iti, Nobuiti Ikeno, Sigeharu Yamada	June	158
Noise in Interface Resistance, H. O. Berktay	Feb.	48
Nomenclature for E.M. Wave Modes, H. M. Barlow, Sept. 233; H. R. L. Lamont	Oct.	261
Note on Dull-Emitter Filaments, N. F. S. Hecht	Feb.	48
Precision Voltage Source, V. H. Attree	Aug.	208
Television Definition, D. A. Bell	Apr.	97
Three-Probe Method of Impedance Measurement, Prem Swarup	June	158
Value of Forecasts, D. A. Bell; C. M. Minnis	July	184
Counter, The Geiger-Müller, (*Editorial*)	Feb.	27
Critical Frequency Variations, T. W. Bennington	July	175
Current Noise in Semi-Conductors (*Correspondence*)	Jan.	23
Cylindrical Aerials (*Correspondence*)	Jan.	24

DELAY, Networks with Maximally-Flat, (*Correspondence*) — June 158
Design of Series Peaking Transformers, A. C. Sim — Apr. 90
Detection of Pulse Signals in Noise, D. G. Tucker and J. W. R. Griffiths — Nov. 264
Diagrams, Circuit, (*Editorial*) — Jan. 1
Differentiating and Integrating Circuits: Spectrum Equalization, G. G. Gouriet — May 112
Dimensional Analysis, Units and Rationalization, (*Editorial*) — Sept. 209
Dipoles, Folded, (*Editorial*) — Mar. 51
Direct-Coupled Power Stage, RC or, E. F. Good — Mar. 54
Direction Finding, Radio, F. Horner — Aug. 187
Distortion and Negative Feedback, Harmonic, R. O. Rowlands — June 133
(*Correspondence*) — Sept. 232, 233; Oct. 261, Nov. 291, 292
Distortion due to Echo Signals, Harmonic, E. G. Hamer and R. G. Medhurst — Nov. 276
Distributed Amplifiers, B. Murphy — Feb. 39
Double-Slug Transformers (*Editorial*) — June 131

ECHO Signals, Harmonic Distortion due to, E. G. Hamer and R. G. Medhurst — Nov. 276

EDITORIALS:

	MONTH	PAGE
Circuit Diagrams	Jan.	1
Dimensional Analysis, Units and Rationalization	Sept.	209
Double-Slug Transformers	June	131
Folded Dipoles	Mar.	51
Geiger-Müller Counter	Feb.	27
Germanium	Aug.	185
Microstrip	Apr.	75
Quantum, The	Nov.	263
Quartz Tuning Fork	July	161
Sintered Magnetic Materials	Oct.	235
Transmission-Line Formulae	May	101
What is the Meaning of Total Rationalization?	Dec.	293

Electrical Oscillations, A. W. Gillies — June 143
Electron Multiplier Valve, A. Lempicki — Dec. 312
Electronic A.C. Potentiometer, L. Tasny-Tschiassny — Dec. 295
Equalization, Spectrum, G. G. Gouriet — May 112
Exhibition, Institution of Electronics — May 130
——, Physical Society's, Mar. 60, May 124; (*Correction*) — June 142
——, Television Society's — Dec. 320
——, 20th National Radio, Aug. 208 — Oct. 255

World Radio History

MONTH PAGE

FARADAY Medal Award .. .. Mar. 72
Feedback Circuits, RC Cathode-Follower, S. C. Dunn .. .. Jan. 10
——, Harmonic Distortion and Negative, R. O. Rowlands, June 133; (*Correspondence*), Sept. 232, 233, Oct. 261, Nov. 291, 292
—— in Triodes, Inherent, H. Stockman .. .. Apr. 94
Filament Structures, Squirrel-Cage, A. M. Hardie .. Aug. 196
Filaments, A Note on Dull-Emitter, (*Correspondence*) Feb. 48
Filter, Termination Variation in the Constant-K, Sidney C. Dunn .. .. Sept. 227
Filtering, Wiener's Theory of Linear, D. A. Bell .. June 136
Filters, Band-Pass, Fuad Surial Atiya .. .. Dec. 307
——, Formulae for Ladder, H. J. Orchard, Jan. 3; (*Correspondence*) Mar. 73, May 123
——, Minimum Inductor or Capacitor, W. Saraga July 163
Folded Dipoles (*Editorial*) .. .. Mar. 51
Formula, New H.F. Proximity-Effect, A. C. Sim .. Aug. 204
Formulae for Ladder Filters, H. J. Orchard, Jan. 3; (*Correspondence*) .. .. Mar. 73, May 123
Four-Terminal Networks, O. P. D. Cutteridge .. Mar. 61

GEIGER-MÜLLER Counter (*Editorial*) .. .. Feb. 27
Germanium (*Editorial*) .. .. .. Aug. 185

H.F. Proximity-Effect Formula, A. C. Sim .. Aug. 204
Harmonic Distortion and Negative Feedback, R. O. Rowlands, June 133; (*Correspondence*) Sept. 232, 233; Oct. 261, Nov. 291, 292
—— Distortion due to Echo Signals, E. G. Hamer and R. G. Medhurst .. .. .. Nov. 276
Height Recorder, Automatic Ionospheric, C. Clarke and E. D. R. Shearman .. .. .. Sept. 211
High-Frequency Bridge with Variable-Ratio Arms, J. E. Houldin and G. T. Thompson .. .. Feb. 32

"IDEAL Coding" versus "Redundancy" (*Correspondence*) .. .. Mar. 73
—— Measurement, Three-Probe Method of, (*Correspondence*) .. .. June 158
—— Measurements, Transmission-Line, H. Sutcliffe July 180
Impedance-Measuring Apparatus, M. P. Beddoes .. Mar. 69
Inherent Feedback in Triodes, H. Stockman .. Apr. 94
Initial Conditions in Transient Analysis, L. Tasny-Tschiassny .. .. Feb. 28
Institution of Electronics, Exhibition .. .. May 130
Interface Resistance, Noise in, (*Correspondence*) .. Feb. 48
Ionospheric Height Recorder, Automatic, C. Clarke and E. D. R. Shearman .. .. .. Sept. 211
—— Storm-Warning Services, C. M. Minnis, May 103 (*Correspondence*) .. .. July 184

JACKSON, Professor Willis .. .. .. Apr. 97

LADDER Filters, Formulae for, Jan. 3; (*Correspondence*) Mar. 73 .. .. May 123

MAGNETIC Materials, Sintered, (*Editorial*) .. Oct. 235
Matching Discontinuities in Waveguides, J. C. Parr .. .. Oct. 243
Measurement: Electronic A.C. Potentiometer, L. Tasny-Tschiassny .. .. Dec. 295
——: The Periodmeter, R. G. Barker and G. L. Connon .. .. Nov. 274
——, Three-Probe Method of Impedance, (*Correspondence*) .. .. June 158
Measurements, Performance: Television Aerials, G. W. Luscombe .. .. Apr. 82
——, Transmission-Line Impedance, H. Sutcliffe .. July 180
Measuring Apparatus, Impedance-, M. P. Beddoes Mar. 69
Microstrip (*Editorial*) .. .. Apr. 75
Microwave Wide-Angle Scanner, J. Brown .. Oct. 250
Miller, W. E. .. .. Oct. 262
Minimum Inductor or Capacitor Filters, W. Saraga .. .. July 163
Multiplier Valve, Electron, A. Lempicki .. .. Dec. 312
Mutual Radiation Resistance of Aerials and Arrays (*Correspondence*) .. .. Jan. 24

NATIONAL Academy of Sciences Research Grants .. .. Nov. 273
—— Radio Exhibition, 20th, Aug. 208 .. .. Oct. 255
Negative Feedback, Harmonic Distortion and, R. O. Rowlands (*Correspondence*) Sept. 232, 233; Oct. 261; Nov. 291, 292 June 133
Network Theorem, Note on a, Leo Storch .. Apr. 77
Networks, Four-Terminal, O. P. D. Cutteridge .. Mar. 61
——, Resistance-Capacitance with Over-Unity Gain, W. Bacon and D. P. Salmon .. .. Jan. 20
—— with Maximally-Flat Delay (*Correspondence*) June 158
New H.F. Proximity-Effect Formula, A. C. Sim .. Aug. 204
Noise, Detection of Pulse Signals in, D. G. Tucker and J. W. R. Griffiths .. .. Nov. 264
—— Factor of Conventional V.H.F. Amplifiers, N. Houlding Nov. 281 .. .. Dec. 299
—— in Interface Resistance (*Correspondence*) .. Feb. 48
—— in Semi-Conductors, Current-, (*Correspondence*) Jan. 23
Nomenclature for E.M. Wave Modes, (*Correspondence*) Sept. 233; .. .. .. Oct. 261
Non-Resonant Sloping-V Aerial, J. S. Hall .. Sept. 223

OSCILLATIONS, Electrical, A. W. Gillies .. June 143

PEAKING Transformers, Design of Series, A. C. Sim .. .. Apr. 90
Periodmeter, The, R. G. Barker and G. L. Connon Nov. 274
Physical Society's Exhibition, Mar. 60, May 124; (*Correction*) .. .. June 142
Potentiometer, Electronic A.C., L. Tasny-Tschiassny Dec. 295
Power Gain of Curtain Arrays of Aerials, P. Hammond .. .. May 108
—— Stage, RC or Direct-Coupled, E. F. Good .. Mar. 54
Precision Voltage Source (*Correspondence*) .. Aug. 208
Propagation: Critical Frequency Variations, T. W. Bennington .. .. July 175
——: Ionospheric Storm-Warning Services, C. M. Minnis May 103; (*Correspondence*) .. .. July 184
——: The Value of Forecasts (*Correspondence*) .. July 184
Proximity-Effect Formula, New H.F., A. C. Sim .. Aug. 204
Pulse Signals in Noise, Detection of, D. G. Tucker and J. W. R. Griffiths .. .. .. Nov. 264

QUANTUM, The, (*Editorial*) .. .. .. Nov. 263
Quartz Tuning Fork (*Editorial*) .. .. July 161

RC CATHODE-FOLLOWER Feedback Circuits, S.C. Dunn .. .. Jan. 10
—— or Direct-Coupled Power Stage, E. F. Good .. Mar. 54
R.I.C. Technical Writing Premium, Awards Apr. 96, Nov. 273
Radiation Patterns, Aerial, T. T. Ling .. .. Aug. 192
—— Resistance of Aerials and Arrays, Mutual, (*Correspondence*) .. .. Jan. 24
Radio Direction Finding, F. Horner .. .. Aug. 187
Rationalization, Dimensional Analysis, Units and, (*Editorial*) .. .. Sept. 209
——? What is the Meaning of Total, (*Editorial*) .. Dec. 293
"Redundancy", "Ideal Coding" versus, (*Correspondence*) .. .. Mar. 73
Resistance-Capacitance Networks with Over-Unity Gain, W. Bacon and D. P. Salmon .. .. Jan. 20
——, Noise in Interface, (*Correspondence*) .. Feb. 48

SCANNER, Microwave Wide-Angle, J. Brown .. Oct. 250
Semi-Conductors, Current-Noise in, (*Correspondence*) .. .. Jan. 23
Sintered Magnetic Materials (*Editorial*) .. .. Oct. 235
Spectrum Equalization, G. G. Gouriet .. .. May 112
Squirrel-Cage Filament Structures, A. M. Hardie .. Aug. 196
Standard-Frequency Transmissions: Jan. 26, Feb. 50, Mar. 74, Apr. 100, May 130, June 160, July 184, Aug. 208, Sept. 234, Oct. 262, Nov. 292, Dec. 320; Schedule, June 160; (*Correction*) July 184
Storm-Warning Services, Ionospheric, C. M. Minnis, May 103 (*Correspondence*) .. .. .. July 184

TECHNICAL Writing Premiums, R.I.C., Apr. 96, Nov. 273
Television Aerials, G. W. Luscombe .. Apr. 82
—— Definition (*Correspondence*) .. .. .. Apr. 97
—— Society's Exhibition .. .. Dec. 320
Termination Variation in the Constant-K Filter, Sidney C. Dunn .. .. Sept. 227

World Radio History

	MONTH	PAGE
Theorem, Note on a Network, Leo Storch	Apr.	77
Three-Probe Method of Impedance Measurement (*Correspondence*)	June	158
Transformers, Design of Series Peaking, A. C. Sim	Apr.	90
——, Double-Slug, (*Editorial*)	June	131
Transient Analysis, Initial Conditions in, L. Tasny-Tschiassny	Feb.	28
Transistors, Bandwidth Limitation of Junction. (*Correspondence*)	Oct.	261
Transmission-Line Formulae (*Editorial*)	May	101
——— Impedance Measurements, H. Sutcliffe	July	180
Triode Transformation Groups, A. W. Keen	Oct.	238
Triodes, Inherent Feedback in, H. Stockman	Apr.	94
Tuning Fork, The Quartz, (*Editorial*)	July	161
U.S. National Academy of Sciences Research Grants	Nov.	273
Units and Rationalization, Dimensional Analysis, (*Editorial*)	Sept.	209
VALUE of Forecasts (*Correspondence*)	July	184
Valve, Electron Multiplier, A. Lempicki	Dec.	312
Valves: Noise in Interface Resistors (*Correspondence*)	Feb.	48
——: Note on Dull-Emitter Filaments (*Correspondence*)	Feb.	48
——: Squirrel-Cage Filament Structures, A. M. Hardie	Aug.	196
——: Triode Transformation Groups, A. W. Keen	Oct.	238
Vibration Test for Valves, C. C. Eaglesfield	Mar	57
Voltage Source, Precision, (*Correspondence*)	Aug.	208
WAVE Modes, Nomenclature for E.M. (*Correspondence*) Sept. 233	Oct.	261
Waveguides, Matching Discontinuities in, J. C. Parr	Oct.	243
What is the Meaning of Total Rationalization? (*Editorial*)	Dec.	293
Wiener's Theory of Linear Filtering, D. A. Bell	June	136

INDEX TO AUTHORS

	MONTH	PAGE
ATIYA, FAUD SURIAL	Dec.	307
BACON, W., and SALMON, D. P.	Jan.	20
BARKER, R. G. and CONNON, G. L.	Nov.	274
BEDDOES, M. P.	Mar.	69
BELL, D. A.	June	136
BENNINGTON, T. W.	July	175
BROWN, J.	Oct.	250
CLARKE, C. and SHEARMAN, E. D. R.	Sept.	211
CONNON, G. L. with BARKER, R. G.	Nov.	274
CUTTERIDGE, O. P. D.	Mar.	61
DUNN, S. C. Jan. 10	Sept.	227
EAGLESFIELD, C. C.	Mar.	57
GILLIES, A. W.	June	143
GOOD, E. F.	Mar.	54
GOURIET, G. G.	May	112
GRIFFITHS, J. W. R. with TUCKER, D. G.	Nov.	264
HALL, J. S.	Sept.	223
HAMER, E. G. and MEDHURST, R. G.	Nov.	276
HAMMOND, P.	May	108
HARDIE, A. M.	Aug.	196
HOULDIN, J. E. and THOMPSON, G. T.	Feb.	32
HOULDING, N. Nov. 281	Dec.	299
HORNER, F.	Aug.	187
KEEN, A. W. Jan. 5	Oct.	238
LEMPICKI, A.	Dec.	312
LING, T. T.	Aug.	192
LUSCOMBE, G. W.	Apr.	82
MEDHURST, R. G., with HAMER, E. G.	Nov.	276
MINNIS, C. M.	May	103
MURPHY, B.	Feb.	39
ORCHARD, H. J.	Jan.	3
PARR, J. C.	Oct.	243
ROWLANDS, R. O.	June	133
SALMON, D. P., with BACON, W.	Jan.	20
SARAGA, W.	July	163
SHEARMAN, E. D. R., with CLARKE, C.	Sept.	211
SIM, A. C., Apr. 90	Aug.	204
STOCKMAN, H.	Apr.	94
STORCH, LEO	Apr.	77
SUTCLIFFE, H.	July	180
TASNY-TSCHIASSNY, L., Feb. 28	Dec.	295
THOMPSON, G. T., with HOULDIN, J. E.	Feb.	32
TUCKER, D. G., and GRIFFITHS, J. W. R.	Nov.	264

World Radio History

INDEX TO WIRELESS ENGINEER
ABSTRACTS AND REFERENCES

VOL. 30. 1953

This index to the Abstracts and References, published monthly in "Wireless Engineer" during 1953, is compiled on the same plan as for 1952, there being both Author and Subject Indexes. A list of the principal journals scanned for abstracting is included with the publishers' addresses.

CONTENTS

page

I.1 ..... Abbreviations
I.2 ..... Author Index
I.36 ..... Subject Index
I.56 ..... Errata
I.56 ..... U.D.C. changes
I.56 ..... List of Journals

SYMBOLS (A) Abstract, (B) Book Review, (C) Note of Correction, (D) Discussion

AUTHOR INDEX A name followed by "and" is that of the first author of a jointly written paper, while the word "with" indicates that the name indexed is that of the second author.

Abbreviations used in the Abstracts and Index

a.c.	= alternating current	c.w.	= continuous wave
d.c.	= direct current	i.c.w., m.c.w.	= modulated c.w.
h.v.	= high voltage		
l.v.	= low voltage	s.w.*	= short wave
a.f.	= audio frequency	u.s.w.*	= ultra short wave
i.f.	= intermediate frequency	λ	= wavelength
r.f.	= radio frequency, including:—	c.r.	= cathode ray
l.f.	= low frequency, <300 kc/s	c.r.o.	= cathode ray oscilloscope
m.f.	= medium frequency, 300–3000 kc/s	d.f.	= direction finding
h.f.	= high frequency, 3–30 Mc/s	e.m.	= electromagnetic, *but*
v.h.f.	= very high frequency, 30–300 Mc/s	e.m.f.	= electromotive force
u.h.f.	= ultra high frequency, >300 Mc/s	a.f.c.	= automatic frequency control
a.m.	= amplitude modulation	a.g.c.	= automatic gain control
f.m.	= frequency modulation	a.ph.c.	= automatic phase control
p.m.	= pulse modulation, including:—	a.v.c.	= automatic volume control
p.a.m.	= pulse amplitude modulation	m.u.f.	= maximum usable frequency
p.c.m.	= pulse code modulation	p.p.i.	= plan position indicator
p.f.m.	= pulse frequency modulation	s.s.b.	= single sideband
p.ph.m.	= pulse phase modulation	d.s.b.	= double sideband
	or	s.w.r.	= standing wave ratio
p.p.m.	= pulse position modulation	v.f.o.	= variable frequency oscillator
p.w.m.	= pulse width modulation	R/T	= radiotelephony
ph.m.	= phase modulation	W/T	= wireless telegraphy
v.m.	= velocity modulation	TV	= television

*No clearly defined limits

World Radio History

AUTHOR INDEX

Aaron, M. R., synthesis of feedback control systems, **3720**
Abadie, —, and — Blondé, Type-PM 53 broadcasting preamplifier, **3567**
van Abbe, H. H., efficiency and damping of diode rectifiers, **1195, 2129**; input impedance and transimpedance of i.f. transformers, **2578**
—— and A. Boekhorst, frame-deflection circuit with voltage-dependent resistor, **3741**
—— and J. Jager, application of Type-DK92 heptode at 30 Mc/s, **813**
—— and others, new trends in a.m./f.m. receiver design, **2427**
Abbot, F. R., design of buried-conductor r.f. ground system, **(C)42**
Aberdam, H., u.h.f. dielectric aerials, **2896**
Abiko, Y., with M. Tomura, electron multiplication in hard flows of Se rectifiers, **2350**
Achard, E., theorem on ideal transformer networks, **1266**
Acheson, M. A., and E. M. McElwee, reliability of valves, **271**
Ackland-Snow, P. E., and G. A. Gledhill, 6-waveform generator and display unit for testing television channel, **1087**
Adam, E., calculation of transient phenomena in electrically short networks by means of Fourier integrals, **1926**
Adams, E., W. M. Hubbard and A. M. Syeles, permanent magnet from powdered MnBi, **1035**
Adelaar, H. H., cathode-follower operation, **(D)1285**
Admiraal, D., sawtooth derivator, **2269**
Adorian, P., television distribution by wire, **1808**; future of British broadcasting, **2445**
Affleck, J. H., with others, double activators in oxide-cathode base alloys, **3152**
Agdur, B. N., experimental observation of double-stream amplification, **3146**
—— and C. G. L. Åsdal, noise measurements on travelling-wave valve, **3145**
Ahrendt, W. R., and J. F. Taplin, Automatic Feedback Control, **(B)840**
Aigrain, P., and H. Bulliard, photomagnetoelectric effect, theory of, **2015**, measurements of in Ge, **2016**
—— and C. Dugas, physical properties and radio applications of semiconductors, **1703**
—— J. Lagrenaudie and G. Liandrat, conductance of semiconductor in electric field, **1695**
Aisberg, É., miniature receivers for Palais de Chaillot translation service, **2794**
Akao, H., T. Takakura and T. Sasaki, dielectric constant of Rochelle salt at 3 kMc/s, **2729**
Akeley, E., with J. Swihart, axial motion of electrons in linear accelerator, **3077**
Akhiezer, A. L., and R. V. Polovin, plasma oscillations in crossed electric and magnetic fields, **3591**
Albagli, S., effect of losses in h.f. transmission lines, **3475**
Albers-Shoenberg, E., with D. R. Brown, ferrites speed digital computers, **2061**
Albright, W. G., with others, meteorological effects on v.h.f. propagation, **1784**
Alers, G. A., internal friction of quartz, **2349**
Alexander, A. E., with J. R. Anderson, theory of vibrating-capacitor converter, **475**
Alexanderson, E. F. W., control applications of transistor, **792**
Alison, W. B. W., and J. C. E. Taylor, direct-reading thermistor bridge, **(D)2740**
Alixant, M., applications of T networks, **1928**
Alkemade, C. T. J., and G. van den Brink, stabilized calibrated 50-c/s voltage source, **1424**
Allard, L. S., design factors of television c.r. tubes, **1540**
Alldredge, L. R., with T. B. Whiteley, photomechanical wave analyser for Fourier analysis of transient waveforms, **1439**
Allen, A. L., long-life d.c. contacts, **3497**
Allen, C. C., with H. R. Meahl, calibrating ammeters at frequencies > 100 Mc/s, **1075**
Allen, F., production of television receivers, **3739**
Allen, P. J., microwave magnetometer, **1072**
Allen, W. A., with P. H. Parkin, acoustic design of auditoria, **3175**
—— with others, acoustics of Royal Festival Hall, **2198**
Allis, W. P., and S. C. Brown, h.f. breakdown of gases, **83**
Allison, C. T., and F. G. Blackler, univoltage e.s. lens for television c.r. tubes, **1541**
Allnatt, J. W., delay equalization of London/Birmingham television cable system, **1148**
Alma, G. A., G. Diemer and H. Groendijk, rubber-membrane model for electron paths, **3756**
Almond, M., J. G. Davies and A. C. B. Lovell, velocity distribution of sporadic meteors, **1009**
—— with G. S. Hawkins, radar observations of major night-time meteor streams, **108**
Alon, I., J. Arsac and J. L. Steinberg, distribution of radio brightness on solar disk at 9·35 kMc/s, **3272**
Alpert, D., production and measurement of ultra-high vacuum, **3603**
Alsberg, D. A., principles and applications of converters for h.f. measurements, **155**; sweep-frequency response of RG-6U cable, **(D)3058**
Altenburg, K., and S. Kästner, demodulation of ultrasonic waves in liquids, **2864**
Althans, W., radio technology and electroacoustics at 1952 Technical Fair, Hanover, **299**
Altrichter, E., interference evaluation by means of noise filters, **2430**
Amakasu, K., noise due to current flow through Ba-Sr oxide coating, **1532**
Ament, W. S., theory of reflection by rough surface, **1106**
An Wang. See Wang, An.
Anders, T., diffraction of acoustic waves at circular aperture, **3170**
Anderson, A. E., transistors in switching circuits, **652**
Anderson, D. V., and C. Barnes, dispersion of ultrasonic pulse transmitted through tube filled with water, **2538**
Anderson, F. B., gain and phase-angle measuring set, **(A)2738**
Anderson, H. L., and others, synchrocyclotron for 450-MeV protons, **1764**
Anderson, J. M., with J. A. Bronzo, plastic lenses for high-intensity ultrasonic radiation, **915**
—— with others, interaction of microwaves in gas-discharge plasma, **2637, 2970**
Anderson, J. R., digital computers, ferroelectric storage elements for, **1053, 3049**, electrical delay lines for, **3650**
—— and A. E. Alexander, theory of vibrating-capacitor converter, **475**
Anderson, J. S., and N. N. Greenwood, semiconducting properties of Cu_2O, **1701**
Anderson, L. J., sensitivity of microphones to stray magnetic fields, **1897**
—— and E. E. Gossard, field-strength prediction for nocturnal duct, **1112**
Anderson, N. S., longitudinal magneto-hydrodynamic waves, **2635**
Anderson, P. A., comparison of methods of contact-potential measurement, **993**
Anderson, R., and J. R. Smith, delayed-trigger oscillograph for television waveforms, **1438**
Anderson, R. S., W. V. Smith and W. Gordy, line breadths of the microwave spectrum of O_2, **91**
Anderson, T. N., high-power microwave dummy loads, **2892**
Anderson, V. C., and P. Rudnick, thermistor-bridge correlator, **3350**
Anderson, W. G., and E. H. Fritze, instrument-approach-system steering computer, **1369**
Anderson, W. N., with A. R. A. Rendall, temporary links for television outside broadcasting, **1143**
André, P., physical properties of araldite, **138**
Andreasen, M., with H. L. Knudsen, theory of plane reflectors in aerial systems, **1913**
Andrejewski, W., diffraction of e.m. waves at conducting circular disk and at circular aperture, **3270**
Andrew, A. M., corona discharge tubes for voltage stabilization, **(D)2803**
Andris, P., with R. E. Beam, input impedance of folded-dipole aerials, **3488**
Angelov, B. P., E. M. Lobanov and S. V. Starodubtsev, action of electron stream on current sensitivity of Se and Ag_2S photocells, **3140**
Angles d'Auriac, H., analysis of signals and of linear transmission operators, **3703**
Anliker, M., W. Känzig and M. Peter, properties of very small ferroelectric particles, **3007**
Antoine, R., with F. P. Pietermaat, h.f. tempering of band-saw teeth, **179**
Aono, Y., world-wide distributions of f_0F_2, **2984**
—— with others graphical calculation of h.f. sky-wave field strength, **2777**
Apker, L., and E. A. Taft, photoconduction in anodic Ta_2O_5, **733**; field emission from photoconductors, **1391**
—— E. Taft and J. Dickey, electron scattering and photoemission from Cs_3Sb, **1690**
—— with E. Taft, photoemission from Cs_2Te and Rb_2Te, **1689**
Applebaum, S., gamma correction in constant-luminance colour-television systems, **238**
Appleton, E. V., 'sluggishness' of ionosphere, **3289**; storm phenomena in ionosphere, **3304**
—— and W. J. G. Beynon, radiocommunication on frequencies exceeding predicted m.u.f. values, **3090**
—— and W. R. Piggott, ionospheric storms and geomagnetic anomalyi n F_2 layer, **2308**
Arata, H., with others, dissociation of oxide-coated cathode, **2834**
Archbold, R. B., probe microphone for measurement of sound pressure, **1898**
Arendt, P. R., adaptation of eye in relation to television transmission, **563**
Arens, W., with H. Holzwarth, modulation equipment for 24-channel p.p.m. beam R/T system, **822**
Arfin, B., with G. A. Espersen, 3-cm magnetron for beacons, **2186**
Argence, É., and M. Mayot, calculation of true heights of ionospheric layers, taking account of geomagnetic field, **3290**
—— K. Rawer and K. Suchy, effect of geomagnetic field on ionospheric absorption of short waves, **1678**
Argirovic M., method of determining conductivity of heterogeneous ground, **3687**
Arima, Y., with H. Uyeda, classification of F_2 layer storms, **2893**
Arizumi, T., and S. Kotani, gettering process of Ba, **2321**
Armitage, M. D., improved stabilization with voltage-regulator tube, **837**
Armstrong, H. L., proof of formula for power of a matrix, **2253**; saturated-diode operation, **(D)2512**; two *RC* oscillator circuits, **2935**
—— with J. H. Simpson, reverse characteristics of Ge rectifiers, **1715**
Armstrong, L. D., production of *p-n* junctions by diffusion of impurity through metal layer, **739**
—— with others, Ge *p-n-p*-junction transistor, **876**
Armstrong, W. J., with others, axial-flow u.h.f. resnatron, **1208**
Arnaud, J. P., choice of television channels and standards in S. America, **1494**
Arnold, A. H. M., a.c. resistance standards, **3360**
Aron, A., Maze counters, **3089**
Arsac, J., with others, distribution of radio brightness on solar disk at 9·35 kMc/s, **3272**
Arsove, M. G., algebraic theory of linear transmission networks, **3229**
Arthur, G. R., narrow-band noise after nonlinear device, **816**; servomechanisms, a survey, **830**

World Radio History

von Arx, E. F., with others, servomechanism transient performance from db/log f plots, **3721**
Arzeliès, H., mean velocity of energy in stratified ionized absorbing medium, **196**; differential equation for e.m. rays in ionized absorbing medium with slowly varying parameters, **1465**
Ascoli, R., coupling of 'scale-of-two' circuits, **950**; theory of compensated delay line, **1262**
Åsdal, C. G. L., with B. N. Agdur, noise measurements on travelling-wave valve, **3145**
Ashcroft, H., W. W. H. Clarke and J. D. S. Hinchliffe, factors affecting performance of coaxial cables for television links, **928**
Ashdown, G., vapotron transmitting valves, **3451**
Ashmead, D., optimum design of linear arrays, **1594**
Ashour, A. A., induction of currents in a disk by sudden creation of magnetic poles, **708**
Ashwell, G. E., with others, measurement of phase velocity of 127·5-kc/s ground wave, **1782**
Aslakson, C. I., new determinations of velocity of radio waves, **1470**
Aspden, H., magnetic permeability measurement for rod specimens, **1429**
Assadourian, F., distortion of f.m. signal by small loss and phase variations, **1484**
—— and E. Rimai, theory of microstrip transmission lines, **622**, **2213**
Astuni, E., power in LRC circuits with nonsinusoidal voltage, **1259**; Heaviside's condition for distortionless transmission, **2560**
Ataman, A., artificial-slot aerials, **1916**
Atkins, A. A., applications of electronics in textile industry, **504**
Atkins, H. J. B., with G. C. Newton, application of television to demonstration of surgery, **1845**
Atkins, I., engineering technique of television programme production, **843**
Atkinson, A. B., with others, factors affecting design of mass-production television receivers, **1496**
Atkinson, P. D., optimum input-winding resistance of magnetic amplifier with voltage feedback, **3210**
Atlas, D., M. Kerker and W. Hitschfeld, scattering and attenuation by nonspherical atmospheric particles, **2314**
Atterling, H., and G. Lindström, 225-cm cyclotron at Stockholm, **506**
Attew, J. E., television-waveform monitor, **1736**
Attree, V. H., feedback-pair video amplifier, **366**; saturated-diode operation of miniature valves, **1197**, **(D)2512**; measurements of saturated-diode stability, **2511**; differential input stage for a.f. amplifiers, **2616**
Attura, G. M., effects of carrier shifts on derivative networks for a.c. servomechanisms, **2452**; magnetic amplifier with reset control, **2581**
Auerbach, I. L., with J. O. Paivinen, design of triode flip-flops for long-term stability, **3558**
Augustin, E., 1952 u.s.w. conference, Stockholm, **1488**
Auld, J. S., U.S. Army Signal Corps mobile television system, **1821**
Aumont, R., and J. Romand, precision measurement of direct voltages by comparison, **2726**
—— with others, variation of resistance of thin metal films as function of applied potential, **3339**
d'Auriac, H. Angles. See Angles d'Auriac, H.
Avazashvili, D. Z., diffraction of e.m. waves, **1972**
Avery, D. G., optical constants of PbS, PbSe and PbTe in 0·5-3μ wavelength range, **2018**
—— and P. L. Clegg, optical constants of single-crystal Ge, **3344**
Awender, H., and K. Sann, activity measurement for quartz crystals in parallel-resonance circuits, **1273**
Axelby, G. S., with others, synthesis of paralleled 3-terminal RC networks, **3536**
Axon, P. E., and W. K. E. Geddes, calibration of disk recordings by light-pattern measurements, **2875**
—— with E. D. Daniel, reproduction of signals recorded on magnetic tape, **2554**
Axworthy, F. R., and J. K. Choudhury, design and application of portable e.s. wattmeter, **1081**

Babcock, W. C., intermodulation interference in radio systems, **1796**
Babin, F., mutual impedance of two thin straight aerials, **2569**
Bache, H., and F. A. Benson, peak-noise characteristics of voltage-regulator tubes, **2516**
Bachman, C. H., G. L. Hall and P. A. Silberg, positive and negative ions in c.r. tubes, **2846**
Bachman, J. F., moving-target indication in pulse radar systems, **2672**
Bacon, G. E., R. Street and R. H. Tredgold, antiferromagnetic properties of CoO-MnO mixtures, **2343**
Bacon, W., and D. P. Salmon, RC circuits with voltage gain, **663**
Badoyannis, G. M., with others, ratio meter measures reflection coefficient, **466**
Bady, I., techniques in measurement of various components, **457**
Baerwald, H. G., and D. A. Berlincourt, electromechanical response and dielectric loss of prepolarized $BaTiO_3$ ceramic, **3168**
von Baeyer, H. J., and R. Knechtli, analysis of multiconductor systems with h.f. TEM waves, **26**
Bähring, H., timebase circuits, **1631**
Bailey, R., control of thyratrons by small signals, **3218**
Bailin, L. L., and M. J. Ehrlich, factors affecting performance of linear arrays, **1241**
—— with H. F. O'Neill, effects of dimensional errors on performance of linear shunt-slot arrays, **1592**
Bailitis, E., C. Hagen and H. H. Rust, variation of partial processes in magnetostriction, **130**
—— with H. H. Rust, ultrasonic-wave generators using dumb-bell type magnetostrictive oscillators, **1556**
Bain, W. C., propagation of 16-kc/s waves reflected obliquely from ionosphere during solar flare, **2769**
Bainbridge-Bell, L. H., arrangement of circuit diagrams, **3492**
Baker, R. H., and others, phase-bistable transistor circuit, **3515**
Baker, W. G., and D. F. Martyn, conductivity of ionosphere, **1352**
Baker, W. R. G., revised specifications for field tests of N.T.S.C. colour television, **2466**
Bakhrakh, L. E., theory of multisegment magnetron, **3158**
Balaam, N. B., G-M counter tubes, **797**
Balmer, J. R., with R. J. Heritage, metallizing glass, ceramic and plastic surfaces, **2346**
Banerjee, B. M., and R. Roy, high-precision ionosphere-sounding equipment, **1677**
Banerji, R. B., studies on random fading characteristics, **2120**
Bangen, G., and H. W. Fastert, fundamentals of probability theory, **197**
Banks, E., with others, rare-earth titanates with perovskite structure, **1717**
Bannon, J. K., R. Frith and H. C. Shellard, humidity of upper troposphere and lower stratosphere over southern England, **1671**
Baños, A., Jr, and R. K. Golden, e.m. field of rotating magnetized sphere, **1334**
Baral, S. S., and A. K. Saha, observations at Calcutta of pulses transmitted from Delhi, **2116**
Barbera, R. C., with W. C. Michels, frequency-eliminating transconductance bridge, **59**
Barbier, M., calculation of third-order aberrations of centred electron-optical systems, **3083**
Barchewitz, P., with F. Cassanas, automatic tracer for electron trajectories, **476**
Bardeen, J., with W. H. Brattain, surface properties of Ge, **1698**
Barden, S. E., electron synchrotron, **182**
Bardócz, Á., and Á. Kemény, electronic spark-timing device, **455**
Bardsley, W., with J. W. Granville, properties of Si point-contact transistors, **2822**
Barducci, I., artificial ears for calibrating telephone receivers, **1888**
Bargain, —, radio installations at French overseas aerodromes, **3419**
Barkechli, M., measurement of intervals of musical scale, **1887**
Barker, R. H., pulse transfer function and application to sampling servo systems, **1131**
Barkla, H. M., and D. M. Finlayson, properties of KH_2PO_4 below Curie point, **2047**
Barkow, P., transmission performance figures for directional p.p.m. systems, **2146**
Barlow, H. M., power-carrying capacity of h.f. waveguides, **(D)27**; input impedance characteristics of antiresonant h.f. transmission lines, **(D)319**
—— and H. G. Effemey, multichannel switch for microwave circuits, **1252**
—— and A. E. Karbowiak, cylindrical surface-wave resonator for determination of velocity of short e.m. waves, **3355**
Barnes, C., with D. V. Anderson, dispersion of ultrasonic pulse transmitted through tube filled with water, **2538**
Barnes, G., with others, field emitter, **3082**
Barnett, S. J., determination of magnetic moment, susceptibility and permeability, **472**
—— and L. A. Giamboni, new gyromagnetic effect in permalloy and iron, **757**
—— with S. Brown, carriers of electricity in metals with positive Hall effects, **700**
Barney, J. M., with A. W. Sullivan, nonlinear statistical filter, **667**
Barnhart, P. W., with others, improved magnetic servo amplifier, **(A)3724**
Barone, A., concentration of ultrasonic energy, **603**
Bartels, B., and M. Munsch, 'conductron' photoconductive camera tube, **3128**
Bartels, G., highly stable receiver for space waves, **2123**
—— with E. A. Lauter, optical refraction and u.s.w. propagation in Baltic area, **521**
Bartels, J., and P. ten Bruggencate, Landolt-Börnstein Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik: Vol. 3—Astronomie und Geophysik, **(B)1359**
—— and J. Veldkamp, international data on magnetic disturbances, first quarter 1952, **401**, second quarter 1952, **1340**, third quarter 1952, **1989**, fourth quarter 1952, **3285**
Barthélemy, R., French origin of image-orthicon target, **2808**
Bartlett, S. C., public-address systems for power stations, **615**, **3470**
—— with others, radio interference tests in field and laboratory, **2431**
Bartley, W. P., and J. E. White, alterations of characteristics of oxide-cathode valves, **3755**
Barton-Chapple, H. J., sound and television signal distribution at South Bank, **23**
Baruch, J. J., shaping of characteristics of nonlinear resistors, **341**
—— and H. C. Lang, analogue computer for use in loudspeaker design, **3050**
Bashara, N. M., fluorinated liquid dielectrics, **(A)3037**
Bassett, H. G., and J. R. Tillman, transient effects in point-contact transistors, **2491**
Batchelder, L., optimum signal characteristics for distance measurement by echoes, **411**
Bates, D. R., reactions in the upper atmosphere, **1342**
—— and G. Griffing, scale-height determinations and aurorae, **3309**
Bates, L. F., post-war developments in magnetism, **87**
Bath, F., and W.v. Werther, carrier-frequency cable links, **2436**
Bauch, F. W. O., new capacitor microphones, **1230**
Bauer, B. B., wear of gramophone needles, **(A)316**; acoustic damping for loudspeakers, **3179**
Bauer, J., terminal equipment for carrier-current telephony systems, **1121**
Baum, R. M., and C. S. Hung, activation energy of heat-treatment-induced lattice defects in Ge, **742**

World Radio History

Baum, R. V., with C. D. Morrill, diode limiters simulate mechanical phenomena, **448**; stabilized electronic multiplier, **3643**
Baumann, E., Fischer large-screen projection system, **2473**
Baumgartner, W., and N. Schaetti, infrared-sensitive electron-multiplier photocell, **1520**
—— with N. Schaetti, dark current of electron-multiplier photocells, **1518, 2492**
Baxandall, P. J., negative-feedback tone control, **64**
—— with S. W. Noble, design of d.c. amplifier based on second-harmonic type of magnetic modulator, **72**
Bayard, M., synthesis of *n*-terminal-pair networks, **1617**
Bayet, M., e.m. properties of plasmas, **1659**
—— and G. Dumas, operation of Penning gauge, **2834**
Bayford, L. J., modern television c.r. tube manufacture, **1870**
Bayliss, A. J., 10-channel pulse-code telemetry system, **498**
Beam, R. E., and P. Andris, input impedance of folded-dipole aerials, **3488**
—— and D. A. Dobson, duo-dielectric coaxial waveguide, **2885**
—— and H. M. Wachowski, shielded-dielectric-rod waveguides, **2218**
Bean, B. R., distribution of refractive-index gradient, **1991**
Beard, C. I., and E. N. Skomal, *RC* commutator for signal/noise improvement, **2784**
Beard, D. M., and A. M. Erickson, auditorium designed for technical meetings, **610**
Beard, E. G., loop aerials for portable broadcast receivers, **3481**
Beard, M., and T. Pearcey, electronic computer, **1050**
Beattie, J. R., and G. K. T. Conn, simple 1·3-c/s oscillator, **2950**
Beatty, R. W., and A. C. Macpherson, mismatch errors in microwave power measurements, **3661**
—— with F. Reggia, u.h.f. magnetic attenuator, **964**
Beauchamp, K. G., blocking oscillators, **2606**
Beaujard, L., elimination of parasitic echoes in ultrasonic flaw detection, **492**
Beaumariage, D. C., with others, transient response of magnetic amplifiers, **2236**
Beaumont, F. H., comparator a.m./f.m. receiver, **2121**
Bechert, K., theory of nonlinear electrodynamics, **1969**
Bechmann, R., thickness vibrations of piezoelectric crystals, **357, 3553**; quartz and synthetic-crystal piezoelectric resonators, **1376**
Beck, A. C., with S. E. Miller, low-loss waveguide transmission, **1585**
Beck, A. H., and A. D. Brisbane, cylindrical magnetron ionization gauge, **3000**
—— and A. B. Cutting, reflex klystrons for cm-wave links, **1546**
Becker, G., G. Bobbert and H. Brandt, measurements of acoustic properties of building materials, **311**
Becker, R., design and performance of medium-wave directive aerial system, **2227**
Becker, W. M., and K. Lark-Horovitz, semiconducting Ge films, **3615**
Beckmann, B., ionosphere conditions and radio 'weather', **2417**
Beckwith, R. W., frequency-shift carrier-current equipment for telemetry and control, **1482**
Beddoes, M. P., impedance-measuring apparatus, **1432**
Bedford, L. H., effect of tube characteristics and other factors on television camera design, **854**
Behling, H., all-wave receiver Type E103AW/4, **207**; input circuit and i.f. amplifier of p.p.m. 24-channel equipment, **1483**
—— G. Brühl and E. Willwacher, dm-wave beam radio equipment FREDA I, **2160**
Behr, A., with H. Siedentopf, ionosphere disturbance of 23rd–28th Feb. 1952, **101**
Behrend, P., theory of pulse technique for coaxial cables, **1905**
Behrent, L. F., r.f.-micropotentiometer resistance elements, **3525**
Behrmann, H., reed-type frequency meter for 5–270 c/s, **1079**
Bekefi, G., diffraction of e.m. waves by aperture, **1293**
Belevitch, V., results and problems of network synthesis, **1616**
Belger, E., measurement and assessment of noise interference, **3406**
Bell, D. A., current noise in semiconductors, **747, 748**; 'ideal coding' *v.* 'redundancy', **1478**; Wiener's theory of linear filtering, **2280**; value of forecasts, **(D)2767**; Information Theory and its Engineering Applications, **(B)2795**; correlation *v.* linear transforms, **(D)3701**; economy of bandwidth in television, **3731**
—— and H. O. Berktay, cathode follower as high-impedance input stage, **367**
—— J. C. Cluley and H. O. Berktay, measurement of cathode temperature of diodes, **1199**
Bell, D. G., and others, electronic band structure of PbS, **2037**
Bell, J., J. A. B. Davidson and E. T. A. Phillips, recent developments in phototelegraphy and facsimile transmission, **557**
Bell, J. S., new focusing principle for proton linear accelerator, **1766**
Belove, C., tolerance coefficients for *RC* networks, **3224**
Belyaev, I. N., and A. L. Khodakov, dielectric properties of $PbTiO_3$ single crystals, **1410**
—— and others, dielectric properties of $BaTiO_3$ single crystals, **3009**
Bemporad, M., with R. Gans, theory of straight aerial, **2220**
Bender, R. S., with others, r.f. power supply, **1134**
Bénè, G. J., determination of nuclear moments from microwave spectra, **1008**
Benedict, T. S., and W. Shockley, microwave determination of collision frequency of electrons in Ge, **2330**
Beneking, H., investigations on dynamic secondary-electron multipliers, **289**
—— with J. Malsch, transistor properties and circuits, **44**
Beneson, L. S., calculation of excitation of waveguides, **2563**
Bengtson, L., with others, integrating amplifier for c.r.o. recording of magnetic flux, **3062**
Benham, W. E., extension of planar-diode transit-time solution, **(D)1862**
de Bennetot, M., experimental investigation of oscillation mode of reflex klystron, **3159**
Bennett, G. S., method for investigating ultrasonic fields, **8**
Bennett, W. P., and H. F. Kazanowski, 1-kW tetrode for u.h.f. transmitters, **1206**
Bennington, T. W., ionosphere review for 1952, **1016**; critical-frequency variations in northern and southern hemispheres, **2657**
—— and L. J. Prechner, B.B.C. ionospheric-storm-warning system, **103**
Benson, F. A., characteristics of glow-discharge voltage-regulator tubes, **(D)267, 591**; waveguide attenuation and surface roughness, **1584, 2881**; accuracy of c.r.o. methods of phase-angle measurement, **1740**; voltage stabilization, **2458**; characteristics of large-current glow-discharge tubes, **3457**
—— and M. S. Seaman, phase-angle measurements with c.r.o., **1739**
—— and J. P. Smith, characteristics of corona stabilizer tubes, **3155**
—— with H. Bache, peak-noise characteristics of voltage-regulator tubes, **2516**
—— with R. M. Pearson, direct-reading thermistor bridge, **1749, (D)2740, (D)3366**
Benson, J. E., methods and colorimetric principles of colour television, **1813**
Benz, F., new modulation method with reduced bandwidth, **3415**
van den Berg, G. J., with others, influence of magnetic field on resistance of Fe films, **1039**
Berger, M., dimensions and units, **86**
Bergmann, W. H., discharges in magnetic fields, **1653**
Bergstralh, T. A., and others, portable 250-kV accelerator, **3679**
van Berkel, P. L. M., Netherlands P.T.T. ionosphere-sounding equipment, **2989**
Berkowitz, A. E., with A. D. Franklin, approach to saturation in dilute ferromagnetic materials, **2337**
Berkowitz, R. S., optimum linear shaping and filtering networks, **2136**; networks with input impedance or transfer admittance of constant magnitude or phase, **2251**
Berktay, H. O., noise in interface resistance, **1530**
—— with D. A. Bell, cathode follower as high-impedance input stage, **367**
—— with others, measurement of cathode temperature of diodes, **1199**
Berlin, H., and G. L. Werner, medium-cost amplifier with good performance, **979**
Berlincourt, D. A., and F. Kulcsar, electromechanical properties of $BaTiO_3$ compositions, **1042**
—— with H. G. Baerwald, electromechanical response and dielectric loss of prepolarized $BaTiO_3$ ceramic, **3168**
Bernard, M., spherical aberration of grid-type electron lenses, **1101**
—— with J. Cordonnier, broadcasting-studio installations and new S.F.R. equipment, **826**
Bernard, M. Y., e.s. lenses, for focusing very-high-energy particles, **1769**, for focusing high-energy particles, **2409**; motion of ions in linear accelerators, **2755, 3079**; focusing of high-energy particles by grid lenses, **3387**
Bernard, P., eleven-year variation of earth's magnetic field, **1337**
Bernardi, L., multichannel radio link between Mestre and Trieste, **3109**
Berndt, W., combined transmitting aerials for television and u.s.w. broadcasting, **37**
Bernstein, M., with A. C. Pritchard, impedance meters for crystal units, **2390**
Bero, O., technical arrangements in Cologne broadcasting centre, **3716**
Berry, F. J., diffraction of sound pulses, by oscillatory long strip, **601**, by nonrigid semi-infinite plane screen, **602**
Berry, S. D., new equipment for outside broadcasts, **224**
Bertein, F., calculation of trajectories in electron optics, **511**; analogy between electron lenses and electrical quadripoles, **2760**; aberrations of electronic images of irregular emissive cathodes, **3081**; representation of optical and electron lenses by resistive quadripoles, **3084**
Berth-Jones, E. W., significance and measurement of intermodulation distortion, **1737**
Berthold, R., and A. Trost, G-M counter arrangement for X-ray interference measurements, **799**
Besthorn, W., mains-loading calculation for quenched-spark h.f. generators, **361**
Bethge, H., construction details of e.s. electron microscope, **2101**
Bevan, P. A. T., B.B.C. television broadcasting stations, **1171**; 100-kW television station, Sutton Coldfield, **1508**
Beyer, R. T., acoustics bibliography, **1. 910, 1549**
Beynon, W. J. G., with E. V. Appleton, radiocommunication on frequencies exceeding predicted m.u.f. values, **3090**
Bhargava, B. N., new early-morning ionospheric phenomenon, **1345**
Bhattacharyya, B. K., admittance and transfer function of *n*-mesh *RC* filter network, **1934**; reproduction of flat top of pulse in amplifier, **3566**
—— with S. K. Sen, triggering of plate-coupled multivibrator by negative pulses, **3557**
Bibl, K., dynamic phenomena in ionosphere, **404**; ionization of the E layer, **721**; new ionosphere sounder, **724**
Bick, J. D., methods of measuring suface induction of magnetic tape, **2552**
Bickford, L. R., Jr., with others, lattice constants and dielectric properties of $BaTiO_3$-$BaSnO_3$-$SrTiO_3$ ceramics, **1718**
Bierl, R., frequency analysis of acoustic phenomena, **1886**; relations between electrical and mechanical production of musical sounds, **3461**
Biermann, L., origin of magnetic fields in moving plasma, **1985**
—— and H. Billing, modern mathematical machines, **1723**
Bies, F. R., attenuation equalizers, **2594**
Biggar, H. P., transfer matrix of passive quadripole, **1604**
Biggs, A. J., and E. O. Holland, British television receiver, **1495**
—— and R. A. Mills, performance of television receiver installations in presence of interference, **1511**

World Radio History

Biguenet, C., and M. Vassilian, gas-filled valves for industrial applications, 295
Billig, E., physics of transistors, 265; effect of minority carriers on breakdown of point-contact rectifiers, 437
—— and J. J. Dowd, *p-n* junction revealed by electrolytic etching, 3332
Billing, H., magnetostatic store for computers, 1724
—— with L. Biermann, modern mathematical machines, 1723
Billinghurst, F. M., with others, automatic-scanning receiver for radio monitoring, 2122
Billottet, H., with P. M. Prache, magnetodynamics of ferrites, 1029
Bingley, F. J., colorimetry in colour television, 3123
Biosca, L. F., with W. Clarkin, valve sockets for industrial equipment, 1860
Bird, A. G., and W. S. McGuire, radio bearer equipment for carrier telephone systems, 3412
Bird, R., computing machines, 3644
Birdsall, C. K., and J. R. Whinnery, waves in an electron stream, 2498
—— G. R. Brewer and A. V. Haeff, resistive-wall amplifier valve, 3147
Birkinshaw, D. C., engineering technique of television programme origination, 842
Bischoff, A. F., quality factor for radar c.r.-tube displays, 2317
Bishop, F. W., objective-aperture centering device for electron microscope, 2758
Bishop, N., noise limiter for mobile v.h.f. receivers, 2780
Bixler, O. C., binaural recording system, 1902
Bizette, H., R. Chevallier and B. Tsai, thermomagnetic properties of haematite, 2705
Bjornson, G. A., graphical network synthesis for a.c. servomechanisms, 2448
Blachman, N. M., information capacities of a.m. and ph.m. systems, 2786; output signal/noise ratio of power-law device, 3405
Blackett, P. M. S., negative experiment on magnetism and earth's rotation, 1333
Blackler, F. G., with C. T. Allison, univoltage e.s. lens for television c.r. tubes, 1541
van Bladel, J., and T. J. Higgins, electromagnetic propagation in layered-dielectric waveguides, 321
Blaha, A., VVB-RFT receivers at the Leipzig Fair, 810
Blair, J. C., J. N. Brown and J. M. Watts, ionosphere recorder for 50 kc/s to 1 Mc/s, 1998
Blake, L. V., number of pulses per beam width for radar, 2671
Blake, R. F., pulse-group coding and decoding by passive networks, 2441
Blanc, D., G-M counters, self-quenching, functioning of, 3086, with external cathode and pure methyl-alcohol filling, 3087
—— and H. Zyngier, application of Wilkinson's theory to G-M counters with external cathode, 3389
Blanc-Lapierre, A., and N. Nifontoff, properties of potential barriers, 2629
Blank, K., with others, thermally produced lattice defects in Ge, 1697
Blankenburg, G., and O. Böttger, dependence of low-temperature conductivity of Cu_2O on oxygen pressure, 1387
—— and K. Kassel, semiconductor properties of Cu_2O in relation to production methods, 1383
—— C. Fritzsche and G. Schubart, dependence of low-temperature conductivity of Cu_2O on oxygen pressure, 1385
Blaquière, A., nonlinear oscillator, perturbed by noise, power spectrum of, 968, 2934, and Nyquist diagram, 1625, 2232; effect of background noise on valve oscillators, 1945
Bleazey, J. C., with others, uniaxial microphone, 2199
Blecher, F., with H. A. Finke, wide-band frequency-sweep generator for testing television equipment, 486
Blet, G., laws governing characteristics of photocells, 3141
Bleuze, J., and P. Dussaussoy, sealing by optical polishing, 141
Blewett, J. P., radial focusing in linear accelerator, 1455
—— with others, origin of 'strong-focusing' principle, 3678
Bliss, J. L., with T. Worswick, television camera with optical view-finder, 856
Bloch, A., measurement of nonlinear distortion, 2734
—— F. J. Fisher and G. J. Hunt, equipment for impedance matching and measurement at v.h.f., 1747
Blodgett, H. C., with others, masking of tones by noise as function of interaural phase, 9
Blondé, —, with — Abadie, Type-PM53 broadcasting pre-amplifier, 3567
Bloom, L. E., with W. W. Cannon, analysis of modulated electron beam, 263
Blow, W., maritime distress frequency, 829
Blum, E. J., asymmetry of dm-λ radiation from sun, 3273
—— with others, radio observations of eclipses on 1st Sept. 1951 and 25th Feb. 1952, 94
Blunden, W. R., with D. M. Myers, C.S.I.R.O. differential analyser, 1049
Boadle, R. D., multichannel microwave relay system, 3110
Boast, W. B., electronic wattmeter, 3669
Bobbert, G., with others, measurements of acoustic properties of building materials, 311
Bobenrieth, A., degassable Penning gauge, 3001
Bock, H., with D. Hopf, circuit technique of new valves for a.m./f.m. receivers, 204
Bödeker, H., with F. Kirschstein, modulation distortion in television reception, 260
Boden, E. H., factors affecting design of v.h.f.-u.h.f. tuners, 3438
Bodle, R. R., Cheltenham 3-hour-range *K*-indices, April–June 1952, 397, July–Sept. 1952, 1336, Oct.–Dec. 1952, 1987, Jan.–March 1953, 3280
Boe, R. C., with K. C. Mathews, application of nonlinear techniques in servomechanisms, 3111
Boekhorst, A., intercarrier-sound television receivers, 857, 3734
—— P. D. van der Knaap and P. A. Neeteson, ECL80 and EQ80 valves in flywheel synchronizing circuits, 2168
Boekhorst, A., with H. H. van Abbe, frame-deflection circuit with voltage-dependent resistor, 3741
Boella, M., television study centre, 3120
Boers, C. J., and A. G. W. Uitjens, line-timebase output stages with booster circuit, 2478
Boersch, H., energy distribution of thermoelectrons in electron-beam devices, 2963
Bogle, A. G., microwave fading on 39-mile optical path over sea, 203
Bohn, L., with E. Meyer, sound reflection at surfaces with periodic structure, 1895
Bohnenstengel, H., rhombic aerial for reception, 2223; reception of frequency-shift signals from s.w. transmitters, 3399
Boljahn, H., with P. Wenk, ultrasonic tinning of Al, 801
Bolle, A., and P. Dominici, calculation of ionospheric absorption of short waves, 1351
Bolle, A. P., equivalent Q of RC networks, (D)3221
Bonifas, H., relation between sparking phenomena and cathode e.s. field, 292; Schottky's equation for thermal electron emission, 1861; new representation of dielectric losses in solid insulating material, 2354
Bonnel, H., with H. Figour, quality estimation for powdered Zr getter material, 3034
Bonnell, C. R., torque type of analogue computer, 2364
Bonner, W. F., and F. J. Oliver, developments in metal rectifiers, 2154
Bonnet, —, accurate frequency meters for range 22–37 kMc/s, 3668
Bonpas, M., with R. Meunier, enamel seal for thin mica windows, 3638
Booth, A. D., digital computer, physical realization of, 447, design of magnetic heads for, 768, logical symbols for circuit elements of, 1052
Borchardt, R. L., citizens'-radio class-A equipment, 2437
Bordewijk, J. L., intermodulation noise in multichannel telephony systems, 827
Boré, G., and W. Rappaport, 'fixed level' recording method for propagation research, 2065
Borgars, S. J., development of vacuum capacitors, 52
Borgnis, F. E., acoustic pressure of plane waves at oblique incidence, 6; physics of sound radiation pressure, 1878; forces due to acoustic wave in viscous medium, 2536
v. Borries, B., F. Lenz and G. Opfer, remanence in soft-iron circuits of magnetic electron lenses, 2102
Borst, J. M., with others, experiments on synthetic speech sounds, 919
Boscher, J., numerical determination of biharmonic functions by means of resistor network, 1727
Bose, H. N., and J. Sharma, decay of long-period afterglow of alkali halides, 2680
Bösenberg, W., and E. Fues, barrier layer of Ge plate rectifier with forward current, 2698
Bosse, G., calculating filter circuits with flattened attenuation curves, 962
Bosse, H., u.s.w. wide-band directive aerial, 636; slotted-cylinder aerials, 2228
Bostick, W. H. and M. A. Levine, demonstration of magneto-hydrodynamic waves in ionized He, 89
Botden, T. P. J., transfer of energy by resonance processes in luminescent solids, 372
Both, E., magnetic-powder cores for military communication equipment, 436
Botsford, J. H., R. N. Lane and R. B. Watson, reverberation chamber with polycylindrical walls, 922
Böttger, O., conductivity measurements on Cu_2O at high temperatures, 1386
—— with G. Blankenburg, dependence of low-temperature conductivity of Cu_2O on oxygen pressure, 1387
Bouchard, J., ionospheric propagation of decametre waves in arctic polar regions, 1783
Bouchier, P., Belgian public mobile R/T service, 3718
Bouix, M., dielectric-rod aerials, 325; modern theories concerning dielectric constant, losses and breakdown, 1692
Boulloud, A., with M. Toitot, discharge between positive point and plane in compressed air, 3265
Bourion, R., semiconductors and oxide cathodes, 1859
Bourrat, J., G. Chaudron and J. Épelboin, effect of dissolved oxygen on magnetic properties of high-purity Fe, 1034
Boursault, P. A., English-French radio dictionary, 597
Bouvier, P., regional-control radar equipment at Orly, 3316
Bowen, W. A., Jr., with others, 'dynamo' currents and conductivities in ionosphere, 1353
Bowers, R. C., with others, electrical properties of glass-fibre paper, 1719
Bowie, R. M., and D. C. Livingston, N.T.S.C. colour-television transmission system, 3124
Bozorth, R. M., and R. W. Hamming, magnetostriction constants of single crystals, 2045
—— and J. G. Walker, magnetostriction of Co and Ni ferrites, 1399; magnetic crystal anisotropy and magnetostriction of Fe-Ni alloys, 2345
Braaten, A. M., with G. S. Wickizer, field strengths at 93 Mc/s over distances of 40–150 miles, 809
Bracewell, R. N., sunspot number series, 2304
Brackmann, J., and J. Frey, copper eddy-current losses in coils with ferrite cores, 3526
—— with others, measurements on high-μ ferrite cores, 1032
Bradfield, G., ultrasonics in solids, 1884
Bradshaw, J. A., calculation of propagation constants of inhomogeneously filled waveguide, (D)624
Brady, J. J., M. D. Pearson and S. R. Peoples, reflection of microwaves by metal-plate structures, 389; compressional phase shifter for microwave measurements, 1440

World Radio History

Bramel de Clejoulx, L., international organization of radio communications and frequency allocation, **2785**
Bramley, A., and J. E. Rosenthal, field-dependent luminescence of vitreous Zn_2SiO_4 phosphor, **418**
Bramsley, G., loop-aerial reception, **35**
Brand, F. A., with others, mechanism of field-dependent secondary emission, **998**
Brandon, P. S., distortion due to f.m. of oscillator by perfect reactance valve, **3104**
Brandt, H., with others, measurements of acoustic properties of building materials, **311**
v. Brandt, R., unitary design system for band-pass filters, **3236**
Brangaccio, D. J., with C. C. Cutler, factors affecting power capacity of travelling-wave valves, **3751**
Branin, F. H., Jr, determination of dielectric constants of absorptive liquids by microwave interferometer, **461**
Brattain, W. H., and J. Bardeen, surface properties of Ge, **1698**
—— with others, electron-spin resonance in Si semiconductor, **3342**
Braun, E. H., gain of e.m. horns, **935**
Braun, K., and H. Koschel, reference-level test equipment for telephone circuits, **777**
Braun, P. B., crystal structure of $BaFe_{18}O_{27}$, **754**
Bray, P. R., power factor and capacitance of mica capacitors at l.f., **1925**
Bray, R., with others, lifetime of injected carriers in Ge, **740**
Bray, W. J., and R. L. Corke, path attenuation measurement for 4-kMc/s radio-relay links, **1091**
—— and D. W. Morris, s.s.b. multichannel operation of s.w. radio links, **2144**
Breckenridge, R. G., semiconducting intermetallic compounds, **2688**
—— and W. R. Hosler, TiO_2 rectifiers, **229**
Brehm, K., power supplies for transmitters, **2454**
Breitenhuber, L., exactly integrable cases of coupled cavity resonators, **1621**
Brekhovskikh, L. M., scattering of waves at uneven surface, **2988**
Bremmer, H., approximate formula for field of magnetic electron lenses, **2099**
Bresler, A. D., approximation in network synthesis, **660, (C)2250**
Brewer, A. W., wide-range electrometer valve voltmeter, **2079**
Brewer, G. R., with others, resistive-wall amplifier valve, **3147**
Bridger, G. W., and C. A. Sempers, compact radar test unit, **1445**
Bridgewater, T. H., Coronation television arrangements, **2804**
Briggs, H. B., and R. C. Fletcher, new infrared absorption bands of *p*-type Ge, **424**
Bril, A., and H. A. Klasens, intrinsic efficiencies of phosphors under c.r. excitation, **3607**; new phosphors for flying-spot c.r. tubes, **3608**
—— with others, single-component white screen for television tubes, **111**
Briner, H., and W. Graffunder, geometrical transformation of impedance diagrams, **2576, (C)3494, 2907**
van den Brink, G., with C. T. J. Alkemade, stabilized calibrated 5?-c/s voltage source, **1424**
Brisbane, A. D., with A. H. Beck, cylindrical magnetron ionization gauge, **3000**
Brittain, F. H., metal-cone loudspeaker, **18, 313**; environment of high-quality reproduction, **611**; relations between subjective and objective tests on loudspeakers, **2202**
Brockelsby, C. F., Wien bridge and applications, **479**
Brockman, F. G., with others, neutron diffraction study of Mg ferrite, **3335**
Broder, J., and P. H. Keck, solubility of Si and Ge in Ga and In, **3033**
—— with others, evaporation of Ge films from carbon crucible, **3032**
Broding, R. A., with others, instrumentation for geophysical exploration, **2749**
Brodzinsky, A., with others, microwave correlator, **1067**
de Broglie, L., Hertzian waves and photons, **709**
Bromber, B. G., and R. D. Hill, Jr, reliability of airborne electronic components, **1939**
Bronwell, A. B., with H. Burroughs, ionized-gas detector for microwaves, **530**
Bronzi, G., new R/T terminal of Centro Radio Nazionale P.T., **2793**
Bronzo, J. A., and J. M. Anderson, plastic lenses for high-intensity ultrasonic radiation, **915**
—— with R. Truell, ultrasonic-attenuation measurements in Ge, **2894**
Brookes, D., with M. B. Williams, cable-fault ndicator, **2392**
Broom, T., effect of temperature of deformation on resistivity of cold-worked metals and alloys, **1027**
Broser, I., and W. Reichardt, effect of pounding on luminescence of ZnS phosphors, **2022**
—— and R. Warminsky, electrical conductivity connected with phosphorescence of CdS crystals, **1023, 1371**
Brous, J., I. Fankuchen and E. Banks, rare-earth titanates with perovskite structure, **1717**
Broussaud, G., with J. C. Simon, u.h.f. band-pass filters, **1933**
Brouwer, D., changes in earth's rate of rotation since 1820, **1332**
Brown, D. A. H., photocell amplifier for infrared spectroscopy, **692**; equivalent Q of RC networks, **2919, (D)3221**
—— and V. Roberts, high-speed infrared spectrometer, **1758**
—— R. P. Chasmar and P. B. Fellgett, construction of thermocouples using semiconducting materials, **3376**
Brown, D. E., with K. Kandiah, high-gain d.c. amplifiers, **172**
Brown, D. R., and E. Albers-Shoenberg, ferrites speed digital computers, **2061**
Brown, G. H., and D. G. C. Luck, principles and development of colour-television systems, **3428**
—— and O. M. Woodward, Jr, radiation characteristics of conical and triangular aerials, **1239**
Brown, H. E., with S. T. Smith, direct-viewing memory tube, **3760**
Brown, J., microwave wide-angle scanner, **3484**
Brown, J. N., with others, ionosphere recorder for 50 kc/s to 1 Mc/s, **1998**
Brown, J. S., and W. Thayer, Jr, high-Q a.f. resonant filters, **351**
Brown, R. H., and C. Hazard, r.f. radiation from supernova (A.D.1572), **95**
Brown, S., and S. J. Barnett, carriers of electricity in metals with positive Hall effects, **700**
Brown, S. C., with W. P. Allis, h.f. breakdown of gases, **83**
—— with D. J. Rose, admittance and electron density of h.f. gas discharge, **463**
Browne, I. C., and N. P. Robinson, cross-polarization of radar melting-band, **1364**
Brownlee, L. D., and E. W. J. Mitchell, variations of lattice parameters of semiconducting oxides, **115**
Bruce, F. M., special c.r.o. techniques, **3371**
Brück, L., phase distortion in travelling-wave valves, **1855**; characteristics of electron beam entering coaxial magnetic field, **2638**
ten Bruggencate, P., with J. Bartels, Landolt-Börnstein Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik: Vol. 3—Astronomie und Geophysik, **(B)1359**
Brühl, G., with others, dm-wave beam radio equipment FREDA I, **2160**
Bruijsten, J., H. Groendijk and M. R. Mantz, Type-E80T valve, synchronization of v.f.o. with, **2816**, multichannel I.G.O. circuits using, **2817**
Bruining, H., improvements in image-iconoscope, **2167**
—— with J. C. Francken, developments in image iconoscope, **3733**
Brunner, R. H., l.f. function generator, **680**
Brust, M. F., with W. J. McKune, subharmonics in series nonlinear circuit, **2929**
Bryan, G. W., Jr, transistor h.v. low-current supply unit, **833**
Bryant, J. H., T. J. Marchese and H. W. Cole, recent developments in travelling-wave valves, **274**
—— with others, low-noise travelling-wave valve, **273, (C)2193**
Bube, R. H., electronic transitions in luminescence of ZnS phosphors, **2879**
Buchanan, T. J., measurement of high s.w.r., **1070**
Buckerfield, P. S. T., parallel-T wide-band d.c. amplifier, **982**
Buckland, B. O., transmitting-valve heat-transfer data, **2195**
Bückner, H., integral occurring in theory of linear servomechanisms, **832**
Budde, W., propagation of space waves, **1774**
Budden, K. G., limiting polarization of radio waves reflected from the ionosphere, **1104**; propagation of atmospherics, **1108**; propagation of very-low-frequency waves, **2773**
Buechler, L. W., low-input-power magnetic amplifiers, **333**
Bulanova, A. I., M. N. Mikhnevich and V. B. Perets, coercive force of nonuniformly magnetized specimens, **3024**
Bulgakov, V. V., realization of correction circuits, **1450**
Bull, C. S., space-charge smoothing factor, **(A)291, 1196**
Bull, E. W., design of deflecting coils for c.r. tubes, **1834**
Bullen, J. M., ionospheric-disturbance index, **3302**
Bulliard, H., with P. Aigrain, photomagnetoelectric effect, theory of, **2015**, measurements of on Ge, **2016**
Bullington, K., transmission beyond horizon at 40 Mc/s–4 kMc/s, **1114**; frequency economy in mobile-radio bands, **1797, 3713**
Buneman, O., circulation in flow of electricity, and Dirac's new variables, **1645**
Burgerjon, J. J., with F. A. Heyn, synchrocyclotron at Amsterdam, **3076**
Burgess, E., high-altitude research, **726**
Burgess, R. E., characteristics and applications of thermistors, **948**; contact noise in semiconductors, **2334**; influence of mobility variation in high fields on rectifier barriers, **2697**
Burgett, M. I., Jr, subjective study of colour-synchronization performance, **3427**
van der Burgt, C. M., parameters of magnet strictive vibrations in ferrites, **3624**
—— M. Gevers and H. P. J. Wijn, measurement methods for properties of ferroxcube materials, **3060**
Burke, P. F. C., with D. C. Rogers, British television relay uses travelling-wave valves, **2330**
Burkowitz, P., theory of single-channel transmission of sound, **1223, 1890, 2869**
Burnett, J. H., improvement of gas-valve grid-circuit reliability, **2517**
Burns, D. O., theorem on linear differential equations, and application to analogue computers, **2721**
—— and C. W. Cooper, harmonic-response-testing equipment for linear systems, **3374**
Burns, K. N., transient response of single-point nonlinear servomechanism, **3112**
Burridge, G. E., and A. S. G. Jong, transmission factors for power-line carrier network, **3704**
Burrill, E. A., and A. J. Gale, electron beams sterilize food, **505**
Burroughs, H., and A. B. Bronwell, ionized-gas detector for microwaves, **530**
Busch, C. W., investigations with pulses on wide-band cables, **2728**
Busignies, H., errors in radio navigation systems, **412**
Butler, K. H., alkaline-earth orthophosphate phosphors, **3610**
Butterworth, J., with others, frequency dependance of mutual conductance of aged oxide-cathode valves, **(A)2338**
Buttler, W. M., boundary-layer noise, in semiconductors, **3022**, in CdS single crystals, **3023**
Byrne, J. S., with W. L. Firestone, reduction of distortion in microwave systems, **2788**

Cacheris, J. C., with others, nonquantized f.m. altimeter, **3311**
de Cadenet, M. J., recording panoramic radar images, **2007**
Cady, W. G., graphical aids in interpreting the performance of crystal transducers, **3164**
Cafferata, H., C. Gillam and J. F. Ramsay, B.B.C. television transmitting aerials, **934**
Cage, J. M., and J. C. Schuder, gas-tube inverter for low direct voltages, **2456**

World Radio History

Cahen, G., perturbations of filtered oscillators, **1279, 1624**; nonlinear electromechanical systems, **3556**
—— and J. Loeb, pull-in of nonlinear oscillators with filtered output, **972**; calculation of attenuation in filtered oscillators, **2449**
Cahn, C. R., with H. Hellerman, linear detection of a.m. signals, **208**
Cairns, J. E. L., small high-speed-scanning television pickup tube, **853**
Calaora, A., with V. Gavreau, absolute calibration of microphones, **3173**
Callaway, J., with F. Herman, structure of Ge crystal, **1699**
Callinan, T. D., R. T. Lucas and R. C. Bowers, electrical properties of glass-fibre paper, **1719**
Camac, M., characteristics of synchrotron beam, **2752**
Camillo, C. C., with others, liquid-dielectric r.f. coaxial cables, **3472**
Campbell, F. W., with R. S. Styles, radar observations of rain from non-freezing clouds, **2004**
Campbell, L. L., with J. R. Wait, fields of dipole in semi-infinite conducting medium, **2109, 3202**; effect of large dielectric constant on ground-wave propagation, **2113**
Canac, F., interference of ultrasonic beams incident on and reflected by plane wall, **1558**; measurement of reflecting power of ceilings, **1896**
Cannon, W. W., and L. E. Bloom, analysis of modulated electron beam, **263**
Cappeller, U., reproduction of pulses by proportional amplifier, **691**
Carbenay, F., correlation between level of atmospherics and intelligibility in km-λ radio link, **105**
Carduner, L., 1952 British National Radio Exhibition, **301**
Carhart, R. R., reflection of sound from ocean layers with temperature change, **3463**
—— with P. S. Epstein, absorption of sound in suspensions and emulsions, **2547**
Carleton, J. T., and W. F. Horton, figure of merit of magnetic amplifiers, **(A)2580, 2912**
Carley, W. S., and E. F. Seymour, high-characteristic-impedance delay lines, **2257**
Carlson, E. V., $BaTiO_3$-ceramic vibration pickup, **2399**
Carlson, R. S., and J. G. Truxal, synthesis of compensation networks for carrier-frequency servomechanisms, **3115**
Caro, D. E., and L. U. Hibbard, wide-range oscillator of high stability, **1628**
—— with L. U. Hibbard, instantaneous measurement of rapidly varying frequency, **1428**
Carroll, J. M., community aerials bring TV to fringe areas, **859**
Carter, R. O., and L. K. Wheeler, phototelegraphy transmitter-receiver using subcarrier f.m., **559**
Casimir, H. B. G., symposium on noise, general introduction, **693**
Caspary, R., and H. Müser, photoconductivity of CdS crystals at relatively high temperatures, **1687**
Cass, N., with H. H. Wieder, f.m. transistor oscillator, **2938**
Cassanas, F., and P. Barchewitz, automatic tracer for electron trajectories, **476**
Cassidy, G. J. A., with D. L. Hollway, equipment for dielectric measurements at 100–360 Mc/s, **481**
Cataldo, J. T., development of 40-V Se rectifier plates, **2457**
"Cathode Ray", resonance curves, **675**
Cauchois, J., measurements on moving-target radar equipment with fixed-target echo elimination, **1446**
Causley, D., with others, flying-spot microscope, **3073**
Cayzac, J., with P. Perilhou, stabilized h.v. rectifier unit for 5kV, 50mA, **2800**
Cazenave, R., double resonance in secondary of two inductively coupled circuits, **1620**
Chai Yeh. See Yeh, Chai.
Chait, H. N., wide-angle-scan radar aerial using Schmidt system, **938**
—— N. G. Sakiotis and R. E. Martin, reduction of loss in ferrite gyrators, **1610**
—— with N. G. Sakiotis, ferrites at microwave λ, **931**
Chalberg, H. W. A., r.f. performance of u.h.f. triode, **1204**
Chambers, L. G., calculation of propagation constants of inhomogeneously filled waveguide, **(D)624**; propagation in waveguides filled with two or more dielectrics, **1907**
Chambers, R. G., anomalous skin effect, **1303**
—— with A. B. Pippard, mean free path of conduction electrons in Bi, **996**
Champeix, R., with others, photomultipliers for counting scintillations, **2181**
Chandler, D. P., with others, transient response of magnetic amplifiers, **2236**
Chaney, J. G., rhombic aerials, free-space radiation impedance of, **2898**, coaxial, coplanar, mutual impedance of, **3197**; simplification for mutual impedance of certain aerials, **3199**
Chang, H., and V. C. Rideout, generalization of modulation spectra, **2790**
Chang, S. S. L., semifinite-terminated filters, **2923**
Chapelle, J., recent applications of synthetic crystals, **1046**
Chaplin, G. B. B., with F. C. Williams, design of transistor trigger circuits, **2914**
Chapman, C. L., Ag/Zn accumulator, **3728**
Chapman, J. H., winds in the ionosphere, **1996**
Chapman, J. J., and others, r.f. properties of 16 insulating materials, **1716**
Chapman, S., aurorae, theories of, **1356**, geometry of radio echoes from, **1357**; morphology of geomagnetic storms, **2645**
Chari, S. S., with others, dependence of sonic intensity at source on absorption coefficient in liquids, **2543**
Charlesby, A., ionic current and growth of thin oxide layers on Al, **2347**
Chasmar, R. P., with others, construction of thermocouples using semiconducting materials, **3376**
Chasson, R. L., and M. L. MacKnight, ethylene and ethyl alcohol as quenching agents in external-cathode G-M counters, **2105**
Chatten, J. B., with others, colour characteristics of flying-spot signal generator, **2807**
Chatterjee, B., effect of geomagnetic field in oblique-incidence ionospheric propagation over equatorial regions, **805**; sporadic E regions at different hours over Calcutta, **3292**; studies in ionospheric absorption, **3690**
Chatterjee, J. S., radiation field of conical helix, **2899**
Chatterjee, S. K., perturbation effects in microwave cavities operating in degenerate modes, **360**; cavity resonators, as circuit elements, **967**, interaction of modes in, **2933**
Chaudron, G., with others, effect of dissolved oxygen on magnetic properties of high-purity Fe, **1034**
Chavance, P., and P. Salort, thick obstacles in waveguides, **3190**
Cheek, R. C., and J. D. Moynihan, carrier-frequency noise on power lines, **3705**
Cheng, D. K., and R. A. Galbraith, stagger-tuned multiloop aerials for wide-band l.f. reception, **3207**
Chernosky, E. J., variation of geomagnetic-activity recurrence interval with solar cycle, **1335**
Chernyi, B. K., with E. V. Singakov, potential distribution in titanate ceramic dielectrics, **439**
Cherry, E. C., and G. G. Gouriet, compression of television signals by recoding, **1154**
Chesnes, A. A., with R. Dressler, sound-on-film recording using crystal, **2209**
Cheston, T. C., and D. H. Shinn, scanning aberrations of radar lenses, **731**
Chevallier, R., with others, thermomagnetic properties of haematite, **2705**
Chhapgar, A. F., with others, harmonic oscillations of quartz plates, **1619**
Chikazumi, S., with others, composition of Cs-Sb photocathodes, **2824**
Chipp, R. D., television control-room lay-out, **863**
Chippendale, R. A., with J. A. Jenkins, high-speed photography by means of image converter, **2751**
Chodorow, M., and S. P. Fan, floating-drift-tube klystron, **1544**
—— E. L. Ginzton and E. J. Nalos, debunching of electron beams constrained by strong magnetic fields, **3459**
Choudhury, D. C., production of E layer in oxygen-dissociation region of ionosphere, **723**
Choudhury, J. K., with F. R. Axworthy, design and application of portable e.s. wattmeter, **1081**
Chow, W. F., and J. J. Suran, transient analysis of junction-transistor amplifiers, **3513**
Christiansen, J., self-quenching parallel-plate vapour-filled counters, **796**
Christiansen, W. N., high-resolution aerial for radio astronomy, **2573**
—— and J. V. Hindman, 1·42-kMc/s emission from galactic hydrogen, **718**
—— and J. A. Warburton, highly directional aerial system for scanning solar disk, **3209**
Churchill, J. L. W., trigger circuits for use with cold-cathode counter tubes, **49**
Ciccolella, D. F., and L. J. Labrie, h.f. crystal units for filter networks, **3552**
Cini, R., with G. Piccardi, potential in electrically shielded space, **1646**
Clark, G. L., with others, interaction of microwaves in gas-discharge plasma, **2637, 2970**
Clark, J. R., low-power blocking oscillators, **2936**
Clark, P. B., valve circuits without anode supplies, **685**
Clarke, C., and E. D. R. Shearman, automatic ionospheric-height recorder, **3356**
Clarke, D. S., with others, factors affecting design of mass-production television receivers, **1496**
Clarke, K. K., Wien-bridge oscillator design, **1278**
Clarke, T. E., r.f. characteristics of capacitors, **(D)51**
Clarke, W. W. H., and L. Jacob, characteristics of l.v. electron immersion objective, **2410**
—— J. L. Goldberg and J. D. S. Hinchliffe, u.h.f. cable measurement equipment, **2393**
—— with others, factors affecting performance of coaxial cables for television links, **928**
Clarkin, W., and L. F. Biosca, valve sockets for industrial equipment, **1860**
Clavier, P. J. M., physical explanation of surface wave on dielectric-coated line, **1906**
Clegg, J. A., velocity distribution of sporadic meteors, **1010**
—— with others, radio reflections from meteor trails, **1979**
Clegg, P. L., with D. G. Avery, optical constants of single-crystal Ge, **3344**
de Clejoulx, L. Bramel. See Bramel de Clejoulx, L
Clemmow, P. C., propagation across a boundary separating two media, **3688**
—— and C. M. Munford, tables of values of wave-theory function for complex arguments, **444**
de Clerck, F., sensitivity of vertical and horizontal television aerials to ignition interference, **1180**
Clewell, D. H., and others, instrumentation for geophysical exploration, **2749**
Clifford, F. G., feedback amplifiers for relaying television signals over coaxial cables, **984**
Cline, J. F., aerial impedance-measuring instrument, **630**
Closs, R. L., J. A. Clegg and T. R. Kaiser, radio reflections from meteor trails, **1979**
Cluley, J. C., with others, measurement of cathode temperature of diodes, **1199**
Coblenz, A., and H. L. Owens, temperature variation of transistor parameters, **883**; theory and applications of transistors, **1957, 2289, 2627, 3021, 3444, 3523**
Cochardt, A. W., origin of damping in high-strength ferromagnetic alloys, **3622**
Cocking, W. T., faulty interlacing, **(D)255**; deflector-coil construction, **574**; d.c. restoration in television, **1500**
Coghlan, A. J. A., Rothman modulation system, **1181**
Cohen, E. R., Rydberg constant and atomic mass of electron, **697**

World Radio History

Cohen, J. W., and H. Grosser, calculation of leakage flux of pendent-armature relays, 387
Cohn, G. I., e.m. transients in cylindrical waveguides, 2887
—— with G. T. Flesher, dielectric loading for waveguide linear accelerators, 2408
Cohn, J., effect of long transmission lines on klystron oscillators, 363
Cohn, S. B., experimental verification of theory of metal-strip delay lens, 3485; microwave measurements on metallic delay media, 3652
—— with K. Tomiyasu, Transvar directional coupler, 2931
Colavita, P. A., compensation of *LC* circuits by negative-coefficient capacitors, 2603
Cole, A. W., and J. A. Smale, picture transmission by radio, 558
Cole, D. P., and others, phosphor-photocell radiation detector, 1103
Cole, G. H., grain-oriented Si-Fe alloys, 3030
Cole, H. W., with others, recent developments in travelling-wave valves, 274
Colli, L., and U. Facchini, discharge mechanism in Ar counters, 1462
Collins, N., and T. C. Macnamara, electronic camera in film making, 1830
Colls, J. A., d.c. amplifiers with low-pass feedback network, 369
Colombani, A., and M. Gourceaux, h.f. resistance of conducting strip parallel to conducting plane, 80
—— with M. Gourceaux, currents induced in wide conductor by narrow conductor carrying h.f., 81
Colombo, S., Dirac's function in mathematical physics, 2621; pass band, general definition of, 3534, width of and distortion of transient, 3539
Comte, G., and A. Ponthus, measurements of attenuation of TE_{01} waves in circular waveguide, 1068; determination of characteristic impedance of coaxial cables, 2732
Conn, G. K. T., with J. R. Beattie, simple 1–3-c/s oscillator, 2950
Conrath, J. R., magnetic-amplifier gapless-core tests, 471
Conturie, L., 'Pierre Bourdan' low-frequency broadcasting centre, Paris, 825
Convert, G., low-noise travelling-wave amplifier valve, 275
Conwell, E. M., properties of Si and Ge, 738; electron mobility in strong e.s. fields, 1302; high-field mobility in Ge with dominant impurity scattering, 3328
—— with P. P. Debye, mobility of electrons in Ge, 425
Cook, C. C., N.B.S. calibration of commercial field-strength meters, 773
Cook, E., binaural disk recording, 2550
Cook, H. F., dielectric properties of water and of blood at microwave frequencies, 139
Cook, W. R., Jr, and H. Jaffe, ferroelectricity in oxides with fluorite crystal structure, 1374, 2324
Cooper, B. F. C., magnetic-drum digit-storage system, 3646
Cooper, C. W., with D. O. Burns, harmonic-response-testing equipment for linear systems, 3374
Cooper, F. S., and others, experiments on synthetic speech sounds, 919
Cooper, G. R., with E. A. Saunders, meter for coupling coefficient of i.f. transformers, 3658
Cooper, S. R., second-order sampling servomechanism, 3420
Cooper, V. J., television transmitters, comparison of high- and low-level modulation for, 567, high-power, Holme Moss, design of, 1161; transient testing of television apparatus, 1065
Cooperstein, M., servo-system comparators, 3113
—— with A. H. Phillips, modulation index of f.m. signals, 3071
Copeland, K., A. C. Downing and A. V. Hill, moving-coil galvanometer of extreme sensitivity, 2076
Coppola, P. P., with R. C. Hughes, electrical conductivity of oxide emitters, 894; bariated tungsten emitters, 1189
Copson, E. T., propagation of sound waves of finite amplitude in a gas, 1875
Corbett, B. D., volume compression and expansion, (D)686
Cordonnier, J., and M. Bernard, broadcasting-studio installations and new S.F.R. equipment, 826
Cordovés, J. Sanchez. See Sanchéz Cordovés, J.
Corey, H. E., with others, observations of dislocations in Ge boundaries, 2693
Corfield, D. N., 427/45-Mc/s converter for Television Society's transmissions, 2809, (C)3434
Cork, E. C., suspended locked-coil-rope television-aerial feeder systems, 929
Corke, D. M., aircraft-vibration research, 491
Corke, R. L., with W. J. Bray, path attenuation measurement for 4-kMc/s radio-relay links, 1091
—— with others, design of linear-phase low-pass filters, 1614
Corliss, L. M. J. M. Hastings and F. G. Brockman, neutron diffraction study of Mg ferrite, 3335
Cornell, J. A., and J. F. Sterner, frequency-sweep oscillator for u.h.f. television band, 487
Corrington, M. S., response of tuned circuit to 'ramp' voltage, 2265
Corson, D. R., radiation by electrons in large orbits, 3380
Cosci, G., and K. Fränz, highly stable power supply, 552
Cosgriff, R. L., stabilization of nonlinear feedback control systems, 1761
Cosslett, V. E., J. Nutting and R. Reed, conference on electron microscopy, Bristol, Sept. 1952, 1771
Costas, J. P., synchronous detection of a.m. signals, 528
Couanault, G., with others, 3 signal generators covering range 20–1200 Mc/s, 1084
Couchet, G., Li+ ions, secondary emission under impact of, 384, reflection coefficient of and energy spectrum of secondary electrons, 2631
Coulon, J., circle diagrams for radio systems, 43; some characteristics of quartz crystals, 140
Courant, E. D., M. S. Livingston and H. S. Snyder, strong-focusing synchrotron, 1454
—— and others, origin of 'strong-focusing' principle, 3678
Covill, D. H., frame-scanning output circuits for wide-angle c.r. tubes, 1507
Cowles, L. G., parallel-T *RC* network, 661
Cox, H. L., Jr, improved 'lock-in' amplifier, 2608
Craig, D. J., with others, single synthetic CdS crystals, 135
Crain, C. M., and J. R. Gerhardt, rapid variations of microwave refractive index of air, 431
—— A. P. Deam and J. R. Gerhardt, measurement of tropospheric index-of-refraction fluctuations and profiles, 1341
Crawford, A. E., ultrasonic tinning for Al, 800; ultrasonic whistles, 1879; metallurgical applications of ultrasonics, 2402
Crawford, G. N., with R. D. Teasdale, cut-off frequency for cylindrical waveguide with coaxial dielectric rod, 2886
Creviston, W., variable power supply unit, 2152
Crompton, E. W., v.h.f. multiband monitor for police and fire-services' transmitters, 544
Cronemeyer, D. C., electrical and optical properties of rutile single crystals, 434
—— with D. H. Rank, infrared absorption of heat-treated Ge, 2678
Crow, R. P., with others, wide-band coupling unit for power-line carrier equipment, 359
Crowther, G. O., cold-cathode voltage stabilizer, (D)1805
Cuccia, C. L., spiral-beam valve modulates 1 kW at u.h.f., 2188, 2500; Harmonics, Sidebands and Transients in Communication Engineering, as studied by the Fourier and Laplace Analyses, (B)3719
Cuker, S., improved blanking circuit, 572
Cullen, A. L., general method for absolute measurement of microwave power, (D)1071; microwave vibration-type wattmeter, 1442
—— and I. M. Stephenson, torque-type wattmeter for 3-cm microwaves, 1082
Cullington, A. L., geomagnetic secular variation in New Zealand, 3282
Culver, R., extrapolation techniques with network analogue solutions, 1416
Cunliffe, A., with others, dielectric constant of water films, 1040
Cunningham, W. J., precision voltage source, (D)168
Curie, D., capture and recapture of electrons in phosphorescence, 1643, 2624
Currie, B. W., P. A. Forsyth and F. E. Vawter, radio reflections from aurora, 3308
—— with R. E. Jensen, orientations of auroral displays in Canada, 3307
—— with others, scattering of 56-Mc/s radio waves from lower ionosphere, 2119
Curtis, K. K., and L. N. Hadley, acoustical interference filters, 912
Curtis, R. C., noise test for magnetic recording media, 2877
Cutler, C. C., and D. J. Brangaccio, factors affecting power capacity of travelling-wave valves, 3751
Cutler, S., R. O'Neill and H. M. Thaxton, application of ergodic hypothesis in calculating autocorrelation function of teleprinter signals, 537
—— with others, autocorrelation function from ergodic hypothesis, 535
Cutteridge, O. P. D., four-terminal networks, 1264
Cutting, A. B., with A. H. Beck, reflex klystrons for cm-wave links, 1546
Cutts, F. W., mobile high-power microwave link for vision and sound, 1159
Czyzak, S. J., and others, single synthetic CdS crystals, 135

Daams, H., dead time of G-M counter, 1464
Daboni, L., calculation of capacitance of cube, 2639
Dacey, G. C., space-charge-limited hole current in Ge, 3329
—— and I. M. Ross, unipolar field-effect transistor, 3445
Daguet, J., synchronization of amplitude-limited oscillators, 1943
Dahlke, W., design charts for planar triodes, 2514
—— with others, measurement of flicker-effect constants, 2725
Dalbert, R., measurement of dielectric properties at 80 c/s–40 Mc/s, 3057
Dalfonso, J., power requirements for transistor circuits, 2797
Dällenbach, W., wave propagation between parallel diaphragm-loaded reflector planes, 3139
Dalman, G. C., design features of 14·5–17·5-kMc/s reflex klystron, 2853
D'Altroy, F. A., and H. Y. Fan, microwave measurements on Ge, 3618
Dammers, B. G., performance of pentode output stages, 1636
—— and others, effects due to curvature of valve characteristics, 1854
—— with others, new trends in a.m./f.m. receiver design, 2427
Daniel, E. D., effect of head and tape constants on magnetic-tape record, 2555
—— and P. E. Axon, reproduction of signals recorded on magnetic tape, 2554
Daniel, J., with others, stability of control systems, 1489
Danko, S. F., auto-sembly technique of circuit fabrication, 355
—— and R. A. Gerhold, printed circuits for transistors, 674
Dänzer, H., oscillation build-up phenomena, 1626
von Dardel, G., E. Hellstrand and C. Taylor, synchronization of pulsed high-energy ion beams, 1448
Darden, R. R., Jr, simple method of coupling toroidal coils, 3554
Date, M., with others, permittivity and permeability of ferrites at 6·6-cm λ, (C)1401
Dauphin, A., bibliography on arithmetical pulse counters, 649
Dauphinee, T. M., isolating potential comparator, 3064
Dauvillier, A., e.s. field at Khartoum during solar eclipse 25th Feb. 1952, 104
Davenport, W. B., Jr, signal/noise ratios in band-pass limiters, 3401
David, J. P., with M. Perrot, deviations from Ohm's law in thin metal layers, 2685
Davids, N., theoretical group heights of reflection of 150-kc/s radio waves, 516
Davidson, J. A. B., with others, recent developments in phototelegraphy and facsimile transmission, 557
Davies, B. F., differential amplifier, (D)1637
Davies, J. G., with others, velocity distribution of sporadic meteors, 1009
Davis, J. K., E-C coated glass resistors, 1253
Davis, R. C., Type-154A glide-slope receiver, 413; prediction of non-stationary stochastic processes, 445

World Radio History

Davison, P. W., with others, two new photomultipliers for scintillation counting, 266
Davy, N., and N. H. Langton, external magnetic field of single thick plate, 2293
—— with N. H. Langton, field above and below infinite corrugated sheet, 2965
Dawe, P. G. M., with G. W. Morris, band-pass filter for 8–13 c/s. 3237
Dawson, G., portable equipment for microwave television link, 1158
—— with others, circuit technique for f.m. microwave links, 220
Dawson, J. W., Ge diodes sealed in glass, 1849
Day, G. A., radar observations of rain at Sydney, N.S.W., 3312
Day, J. P., with others, propagation phenomena on microwave line-of-sight links, 1785
Deam, A. P., with others, measurement of tropospheric index-of-refraction fluctuations and profiles, 1341
Dean, C. E., with R. J. Lindeman, tuner for u.h.f. television band, 1166
Deards, S. R., matrix elements of passive networks, (D)3227
Dearing, J. B., and others, multiple television and f.m. aerial system, 1589
Deatherage, B. H., with others, masking of tones by noise as function of interaural phase, 9
Déb, S., nitrogen in the upper atmosphere, 402; current division in planar positive-grid triode, 1533
De Barr, A. E., digit storage using ferromagnetic materials, 3351
Debye, P. P., and E. M. Conwell, mobility of electrons in Ge, 425
Dedell, T. R., magnetic sound tracks for motion-picture film, 2208
Dehmelt, F. W., with J. Malsch, apparatus for drawing Ge single crystals, 2707
Deibert, C. R., F. T. Turner and R. H. Snider, high-speed direct-scanning facsimile system, (A)841, 3730
Deise, L. F., and H. J. Morrison, high-power a.f. amplifiers, 2948
Delattre, P. C., with others, experiments on synthetic speech sounds, 919
Delcroix, J. L., magnetron in cut-off state, 1210
Dell, H. A., pulse-operated timebases, 1630
Delobeau, F., F_{1-2} layer at Dakar and motion of sun, 1347
Delrieu, A., tests of electrical equipment under tropical conditions, 1713
Demus, E., testing television studio equipment by means of variable-phase pulses, 3373
Denis, M., travelling-wave-valve feedback oscillators and theory of reflex travelling-wave valve, 276
Denisov, N. G., propagation of e.m. signals in ionized gas, 198
Denisse, J. F., geomagnetic activity, and solar radio activity, 1011, control of by sunspots, 2642
—— E. J. Blum and J. L. Steinberg, radio observations of eclipses on 1st Sept. 1951 and 25th Feb. 1952, 94
Dennis, N. T. M., with others, working fluids for diffusion pumps, 1686
Dent, H. B., two-range test oscillator, 485
Denton, R. F., T. A. Wilson and A. R. Margolin, a.f.c. of high-power klystrons, 2942
Deppermann, K., and W. Franz, theory of diffraction by cylinder, taking account of surface wave, 1665
Deryugin, L. N., distribution of current in disk rotating in magnetic field, 1313
Desoyer, K. V., motion of ferromagnetic particles in rotating magnetic field, 1664
Destriau, G., excitation of luminescence by variable electric fields, 3255; electroluminescence, a new source of light, 3256
Deutsch, J., and O. Zinke, screening of test rooms and instruments from e.s. fields, 3116
Deutsch, K. H., television in Great Britain, 3732
Deutsch, S., design of unequal-Q double-tuned transformers, 3499
Devey, G. B., Russian radio and electronics, 2525
DeVore, H. B., photoconductivity study of activation of BaO cathodes, 1529
DeWolf, N., testing u.h.f. mixer crystals, 2083
Dickenson, C. R., telecommunications in Nyasaland, 1119
Dickey, J., with others, electron scattering and photoemission from Cs_3Sb, 1690
Dickinson, F. R., with others, amplifiers for L3 coaxial-cable system, 3411
Dickinson, J. T., international monitoring station at Jurbise-Masnuy, 3416
Dickson, A. W., use of servo techniques in design of amplitude-stabilized oscillators, 2937
—— and W. P. Murden, vibrating-wire high-Q resonator, 3561
Dickson, F. H., and others, v.h.f. transmission over mountainous path, 3396
Dickson, J. H., radar chart-matching devices, 1022
Dickten, E., with others, junction-transistor tetrode for h.f., 677, 1184
Diebold, B. A., with A. W. Rogers, components and materials for reliable electronic equipment, 2261
Diemer, G., valve noise at v.h.f., 907
—— and K. S. Knol, valve noise at v.h.f., 3758
—— with K. S. Knol, h.f. diode admittance with retarding field, 290
—— with others, rubber-membrane model for electron paths, 3756
Dieminger, W., causes of excessive absorption in ionosphere on winter days, 519
Diestel, H. G., with E. Meyer, room-acoustics investigations with directive transmitters and receivers, 12
Dietrich, E., radio links in U.S.A., 545
Dike, S. H., difficulties with present solutions of Hallén's integral equation, 633
—— and D. D. King, gain and back-scattering cross-section of cylindrical aerial, (D)2894
Dikhoff, J. A. M., with others, single-component white screen for television tubes, 111
Dingle, R. B., magnetic properties of metals, 1004, 1005; solution of Schrödinger equation for special cases of electron motion, 1648; magnetic properties of cylindrical system of electrons, 1967
Dippner, H., and H. J. Zemke, reverberation times of Berlin auditoria and sound-recording studios, 3467
Dishal, M., alignment of multiple-resonant-circuit filters, (C)1268; minimum number of resonators and minimum no-load Q required in filters, 3543
Ditzenberger, J. A., with C. S. Fuller, diffusion of Li into Ge and Si, 3616
Dixon, G. J., with R. F. Hansford, remote display of radar pictures, 2005
Doak, P. E., reflection of spherical acoustic pulse by absorbent infinite plane, 914
Dobrin, M. B., with others, instrumentation for geophysical exploration, 2749
Dobson, D. A., with R. E. Beam, duo-dielectric coaxial waveguide, 2885
Dobson, G. M. B., ozone in earth's htmosphere, 1015
Dodds, W. J., R. W. Peter and S. F. Kaisel, developments in travelling-wave valves, 1524
Doehler, O., with others, amplification by space-charge waves, 278, oscillations in whole-anode magnetron related to, 904; natural oscillations and mode changes in multicavity magnetrons, 1543; new magnetron oscillator with interdigital circuit, 2187
Doelz, M. L., and J. C. Hathaway, electromechanical i.f. filters, 1615
Doherty, S. N., E. Jones and B. R. Overton, television valves and a.c./d.c. receivers, 1503
Dolan, W. W., with others, field emitter, 3082
Doland, G. D., servomechanism theory applied to television a.f.c. circuit design, 3119
Dolgikh, G., with others, electrical properties of Sb_2S_3 and Bi_2S_3, 3019
Domb, C., tables of functions in theory of diffraction of e.m. waves by the earth, 1777
Dominici, P., measurement of ionospheric absorption, 2661
—— with A. Bolle, calculation of ionospheric absorption of short waves, 1351
Doolittle, H. D., design of high-power valves for industrial heating applications, 3759
Doremus, J. A., R. P. Crow and W. H. Freeman, wide-band coupling unit for power-line carrier equipment, 359
Dorgelo, E. G., 100-kW transmitting valves with thoriated-tungsten filaments, 2841
Dormont, H., calculation of contact potentials, 2286, 2287
—— and E. Morilleau, photomultipliers and detection of nuclear particles, 3748
—— with others, photomultipliers for counting scintillations, 2181
Doty, R. L., with L. W. von Tersch, automatic ejection from betatrons and synchrotrons, 3677
Douglas, A., 'chord' organ, 616
Dow, O. E., time-division multiplex terminal equipment, 212
Dow, W. G., with others, dynamic probe measurements in ionosphere, 3291
Dowd, J. J., with E. Billig, p-n junction revealed by electrolytic etching, 3332
Downing, A. C., with others, moving-coil galvanometer of extreme sensitivity, 2076
Drechsler, M., and E. W. Müller, field electron emission of crystal surfaces, 1963
Drenick, R., servomechanism requiring variable elements, 1800
Dressler, R., post-deflection-focusing chromatron, 3131
—— and A. A. Chesnes, sound-on-film recording using crystal, 2209
Drexler, G., and H. H. Voss, multistage band-pass filter with optimum approximation to rectangular response curve, 1613
Dreyfus-Graf, J., phonetic typo-sonograph, 1568
Dropkin, H. A., with others, nonquantized f.m. altimeter, 3311
Droscher, G., with H. Ehlers, Hinsbeck relay station for television of Coronation, 3425
Druet, Y., bistable high-speed switching circuit, 648
Druzhinin, V. V., and R. I. Yanus, anisotropy of coercive force in single crystals of Si-Fe alloys, 2704
Drysdale, C. V., and A. C. Jolly, Electrical Measuring Instruments: Part 1, (B)2398
Duerdoth, W. T., design of amplifiers for Birmingham/Manchester coaxial cable, 977
Duffin, W. J., 3-probe method of microwave impedance measurement, 462
Duffy, P. A., with others, phosphor-photocell radiation detector, 1103
Dufour, C., and A. Herpin, propagation of e.m. waves in transparent periodically stratified medium, 3589
Dufour, J., directional reception pattern of rhombic aerials, 1912; u.s.w. propagation over the Alps, 3397; u.s.w. propagation and meteorology, 3694
—— with H. Laett, the Dôle as site for television transmitter, 2166
Dugas, C., with P. Aigrain, physical properties and radio applications of semiconductors, 1703
Duhamel, R. H., optimum patterns for endfire arrays, 2225
Duinker, S., graphical analysis of steady-state response of nonlinear networks, 3540
Dujardin, I., and others, electronic tachometer, 2747
Dukat, F. M., and I. E. Levy, cathode-interface effects in television receivers, 2505
Düker, H., with G. Möllenstedt, emission-microscope surface images obtained with electrons due to oblique bombardment by ions, 2757
Dumas, G., with M. Bayet, operation of Penning gauge, 2634
Dummer, G. W. A., and D. L. Johnston, printed and potted electronic circuits, 2926
Dumontet, P., amplifier for weak photoelectric currents, 329
Dumoré, J. M., with others, temperature distribution at end of hot wire, 283
Dunbar, A. S., theory of aerial-beam shaping, 31; effects of astigmatism on diffraction pattern and gain of microwave lens, 1597
Duncan, D. B., response of linear time-dependent systems to random inputs, 2856
Dungan, R. H., D. F. Kane and L. R. Bickford, Jr, lattice constants and dielectric properties of $BaTiO_3$-$BaSnO_3$-$SrTiO_3$ ceramics, 1718

World Radio History

van den Dungen, F. H., integral variant associated with wave equation, **144**
Dungey, J. W., theories of magnetic storms and aurorae, **1013**
Dunkley, R. A. G., with others, circuit technique for f.m. microwave links, **220**
Dunlap, W. C., Jr, with J. S. Saby, impurity diffusion and space-charge layers in fused-impurity semiconductors, **3020**
Dunn, S. C., screen dissipation of pentodes, **294**; *RC* cathode-follower feedback circuits, **662**; termination variation in constant-*k* filters, **3233**
Dunning, K. L., with others, portable 250-kV accelerators, **3679**
Dunsheath, T. J., with J. A. M. Lyon, correlation of temperature and electric-field strength during dielectric heating, **500**
Durand, E., determination of electron trajectory, **2096**, by successive integrations, **1767**; general solutions of Maxwell's equations, **2294**
Durand, É., with others, portable 250-kV accelerators, **3679**
Durand, H. L., with L. A. Finzi, rules of similitude for magnetic-amplifier systems, **334**
—— with others, effective feedback ratio of magnetic amplifiers, **3510**
Durandeau, P., measurement of axial field of magnetic electron lens, **1743**
Dusailly, J., electronic control of soldering machines, **193**
Düsing, W., hermetic glass/kovar seals, **2711**
Dussaussoy, P., with J. Bleuze, sealing by optical polishing, **141**
Dussine, R., bibliography on storage systems in digital computers, **3648**
Dutta, A. K., relaxation mechanism of ultrasonic absorption, **604**
Dutton, J., S. C. Haydon and F. L. Jones, time lags in electrical breakdown of gases, **3262**
D'yakov, G. P., theory of magnetostriction in strong fields, **3028**
Dyall, W. T., G. R. Fadner and M. D. Harsh, improved 'graphechon' storage tube, **1539**, **2845**
Dyatlovitskaya, B. I., photoelectric effect in Sb-Cs cathodes, **416**
Dyke, W. P., and others, field emitter, **3082**
Dykman, I., Kiev conference on cathode electronics, **892**
Dyott, R. B., launching of e.m. waves on a cylindrical conductor, **320**
Dzhakov, E., formulae for saturation current of diodes, **2513**
Dzimianski, J. W., with others, r.f. properties of 16 insulating materials, **1716**

Early, J. M., effects of space-charge-layer thickness in junction transistors, **874**
Earp, C. W., recent development in communication technique, **2433**
Eaton, J. E., spherically symmetrical microwave lenses, **1596**
Ebel, H., perception of a.m. tones, **1883**
—— and P. Maurer, new anechoic chamber of Technische Hochschule, Karlsruhe, **1889**
Ebers, J. J., 4-terminal *p-n-p-n*-junction transistors, **878**
Eckardt, W., pulse oscillograph, **3667**
Eckart, C., scattering of sound from sea surface, **2541**
Eckart, F., luminescent layers with polyvinyl alcohol as protective colloid and binder, **2955**; noise measurements on thin PbS layers, **3003**; development of secondary-electron multipliers, **3139**
Eckart, G., echoes of acoustic waves in stratified troposphere, **1880**
—— and P. Liénard, electrical and acoustical characteristic impedances, and echoes in stratified media, **4**
Edelman, S., with others, long-tube method for determination of sound absorption, **13**
Edson, W. A., Vacuum Tube Oscillators, **(B)2618**
—— and R. D. Teasdale, susceptance slope and selectivity in oscillator design, **2928**
Edwards, L. C., COZI communication-zone indicator, **3600**
Edwards, P. J., search for perfect raster, **3439**
Effemey, H. G., with H. M. Barlow, multichannel switch for microwave circuits, **1252**
Efrussi, M. M., with B. D. Tartakovski, testing sound-absorbing materials, **3466**
Egli, J. J., u.h.f. relay engineering, **1126**
—— with others, v.h.f. transmission over mountainous path, **3396**
Ehlers, H., and G. Dröscher, Hinsbeck relay station for television of Coronation, **3425**
Ehmert, A., d.c. amplifiers with negative feedback, **1950**
—— and R. Mühleisen, high-resistance direct-voltage valve voltmeter for ± 500 V, **2078**
Ehrbar, R. D., with others, L3 coaxial-cable carrier system, **3409**
Ehrenspeck, H. W., input impedance of thick cylindrical aerials, **1235**
Ehrlich, M. J., with L. L. Bailin, factors affecting performance of linear arrays, **1241**
Eich, P., broadcasting station on the Hoher Meissner, **222**
Eichacker, R., determination of network parameters at v.h.f., **1435**
Eicke, H., with A. Schulze, Au-Cr standard resistors, **772**
Eisenberg, A., comparative absorption-coefficient measurements, **1570**
Eisenmann, L., electrical and optical properties of copper sulphides, **1028**
Eisenstein, A., H. John and J. H. Affleck, double activators in oxide-cathode base alloys, **3152**
Ekelöf, S., and others, integrating amplifier for c.r.o. recording of magnetic flux, **3062**
Ekstein, H., and T. Schiffman, response of linear network to frequency-sweep input, **664**
Elghozi, G., a problem of radio d.f., ionospheric anisotropy, **2318**
Eliason, M. C., and W. G. Hornbostel, acoustic firing-error indicator, **192**
Elkind, M. M., ion optics of long h.v. accelerator tubes, **2089**
Ellenwood, R. C., and E. H. Hurlburt, determination of impedance with double-slug transformer, **774**
—— and W. E. Ryan, u.h.f. matching termination, **1073**
Elliot, E. W., with G. J. Hunt, sine-squared pulse, **3377**
Elliott, W. S., design of cavity-type power amplifier, **2949**
Ellis, G. R., F-region triple splitting, **3295**
Ellison, C. H., with others, portable 250-kV accelerators, **3679**
Elmendorf, C. H., and others, L3 coaxial-cable carrier system, **3409**
Elsas, A., and E. Vogt, reversal of sign of magnetostriction by expansion, **1711**
Elsner, H., metallized-paper capacitors, **344**
Elson, D. W., with E. G. Hamer, a.f. combining system for space-diversity receivers, **2426**
van Embden. H. J. Meerkamp. See Meerkamp van Embden, H. J.
Emerson, W. H., with others, properties of ferrites at v.h.f., **1312**
Emms, E. T., theory and design of cathode-follower output stages, **3247**
Endres, R. O., with others, transistor oscillators, **45**
Enenstein, N. H., and M. E. McMahon, pulse response of junction transistors, **3514**
Ener, C., A. F. Gabrysh and J. C. Hubbard, ultrasonic velocity and absorption in air, **7**
Eng, J. W., with W. H. Hannahs, production control of printed resistors, **47**
Engberts, D., voltage conversion at high power, **1490**
Enge, H. A., combined current integrator and microammeter, **1431**
Engelberger, J. F., and H. W. Kretsch, electromechanical transducer for telemetry, **2412**
Engelmann, H. F., with D. D. Grieg, microstrip for kMc/s range, **621**, **2212**
England, R. D., and W. E. Ogle, betatron monitor and integrator, **2754**
Enkel, F., memory for acoustic effects, **306**; electroacoustic production of sound effects, **3177**; supervision of electroacoustical equipment in Cologne broadcasting centre, **3717**
Ensing, L., and H. J. J. van Eyndhoven, oscillator with constant output voltage, **2939**
Épelboin, I., with others, effect of dissolved oxygen on magnetic properties of high-purity Fe, **1034**
Epstein, D. W., colorimetric analysis of R.C.A. colour-television systems, **3429**
Epstein, H., and O. Stram, magnetostrictive ultrasonic delay line, **2057**
Epstein, J., and D. W. Peterson, field-strength surveys for u.h.f. television, **523**; experimental study of wave propagation at 850 Mc/s, **2423**
Epstein, P. S., and R. R. Carhart, absorption of sound in suspensions and emulsions, **2547**
Erginsoy, C., energy states of impurity carriers, **1382**
Erickson, A. M., with D. M. Beard, auditorium designed for technical meetings, **610**
Erny, M., resistance of thin Pt films subjected to direct voltage, **3577**
Esaki, L., thermal treatment of Si rectifiers, **1714**; properties of heat-treated Ge, **2333**; resistivity and thermionic emission of Si, **3333**
Esau, A., characteristics of parabolic reflectors in absorbing media, **3206**
Esche, R., ultrasonic absorption in animal tissues and plastics, **1562**
Eshbach, J. R., and M. W. P. Strandberg, Zeeman-effect measurements on microwave spectra, **1318**
Eshleman, V. R., with others, transmission by reflection from meteoric ionization, **2117**
Espersen, G. A., and B. Arfin, 3-cm magnetron for beacons, **2186**
Esselman, W. H., steady-state analysis of self-saturating magnetic amplifiers, **2235**
Essen, L., stable microwave oscillator for measurement of variations of atmospheric refractive index, **1085**; refractive indices of water vapour, air, O_2, N_2, H_2, D_2 and He at 9·2 kMc/s, **2062**; 1953 Washington conference on h.f. electrical measurements, **3651**
Estrabaud, S., effects of solar eclipse, 25th Feb. 1952, on F_2 region over equatorial Africa, **1327**, on E region over equatorial Africa, **1994**; investigation of ionospheric absorption, **(D)3305**
Ettinger, G. M., magnetic amplifier with high input impedance, **336**
Etzold, H., storage methods of sound measurement, **3464**
Euler, J., electrets, **74**
Evans, J. H., noise factor of cm-wave superheterodyne receivers, **1790**
Everett, R. R., Whirlwind I computer, **446**
Everhart, E., and P. Lorrain, Cock.roft-Walton voltage-multiplying circuit, **2151**
Ewen, A. B., with F. C. Owen, transmitter drive unit for s.s.b. multichannel operation of s.w. radio links, **2175**
Exner, M. L., sound insulation by means of rubber and steel springs, **608**
—— and W. Hampe, determination of damping of pulsating air bubbles in water, **2534**
Eyfrig, R., effect of moon on height of F_2 layer, **405**
van Eyndhoven, H. J. J., with L. Ensing, oscillator with constant output voltage, **2939**

Facchini, U., with L. Colli, discharge mechanism in Ar counters, **1462**
Fadner, G. R., with others, improved 'graphechon' storage tube, **1539**, **2845**
Fagen, M. D., performance of ultrasonic vitreous-silica delay lines, **347**
Fahnestock, J. D., transistor hearing aids, **1903**
Fahrnkopf, C. D., with others, radio interference tests in field and laboratory, **2431**
Fairweather, A., metallic contacts at low voltages in adverse environments, **3496**
—— F. F. Roberts and A. J. E. Welch, structure and properties of ferrites, **2043**
Falkenhagen, H., and G. Kelbg, optical method for determining permittivity and permeability, **995**
Fan, H. Y., with F. A. D'Altroy, microwave measurements on Ge, **3618**
—— with others, lifetime of injected carriers in Ge, **740**; grain-boundary barriers in Ge, **1406**
Fan, S. P., with M. Chodorow, floating-drift-tube klystron, **1544**
Fanguin, R., with G. Raoult, frequency-stabilized u.h.f. discriminator, **2386**
Fankuchen, I., with others, rare-earth titanates with perovskite structure, **1717**
Fannin, B. M., Sommerfeld's surface wave, **(D)3391**
Farley, B. G., dynamics of transistor negative-resistance circuits, **641**

World Radio History

Farr, K. E., compatible colour-television receiver for N.T.S.C. system, **1501, 3130**
Fassbender, J., and B. Seraphin, growth and decay of photoconductivity of CdS single crystals, **1688**
Fastert, H. W., with G. Bangen, fundamentals of probability theory, **197**
—— with F. von Rautenfeld, problems of u.s.w. coverage. **2139**
Faulkner, H., permanent cable and radio links for television relays, **1142**
Favre, R., and C. Haenny, construction and characteristics of Maze-type counters, **2106**
Fechner, P., study of magnetron in cut-off condition, **594**
Fegert, H., phase bridge for measurements on television apparatus, **2391**
Feher, K., with A. Schoch, investigation of sound transmission through partitions, using models, **609**
Feinstein, J., atmospheric reflection of e.m. waves at refractive-index gradients, **1780**; decay of meteor trail, **1977**; wave propagation in anisotropic inhomogeneous medium. **3393**
Feldman, C., protection of Mo films by SiO coatings, **429**
—— and B. Vodar, conduction of Pt films covered with dielectric layers, **134**
Feldtkeller, R., change of shape of hysteresis loop of transformer sheet, **126**; perception of nonlinear distortion in combined tones, **304**
—— and O. Kolb, complex permeability of high-μ ferrite core, **1705**
—— and G. Sorger, magnetic after-effects, **2041**
Felker, J. H., digital computer, regenerative amplifier for, **769**, transistor units for, **1729**
Fellgett, P. B., with others, construction of thermocouples using semiconducting materials, **3376**
Felsen, L. B., and N. Marcuvitz, slot coupling of rectangular and spherical waveguides. **3193**
Felsenheld, R. A., with others, high-gain loop aerial for television broadcasting, **1236**
Ferber, L. W., with G. A. del Valle, wear of magnetic heads. **2203**
Ferguson, A. E., parameters of four-terminal network, **2252**
Ferrero, M., and G. G. Sacerdote, measurement of acoustic impedance, **2545**
Ferris, H. G., effect of viscous dissipation in spherical acoustic resonator, **1564, (C)3172**
Fert, C., paraxial electron trajectories in e.s. lenses, **510**
—— and R. Saporte, electron miscrocopy by reflection. **1457**
Fesenko, E. G., with others, dielectric properties of $BaTiO_3$ single crystals, **3009**
Fetzer, V., numerical calculation of filters, with generalized parameters, **(C)56**, of Tchebycheff type, **668**
Feuer, P., electronic states in crystals under large perturbations, **736**
Feyer, J. A., impulse e.m. fields, **(D)1591**
Fialkow, A. D., and I. Gerst, maximum gain of *RC* network. **1606**
Fick, H., fundamentals of f.m. by means of reactance units. **2820**
Fife, S. L., critical capacitance coupling for television sound reception. **1831**
Figour, H., and H. Bonnel, quality estimation for powdered Zr getter material. **3034**
Finch, H. W., with M. G. Hammett, β-particle and γ-ray thickness gauges, **496**
Finch, T. R., and R. W. Ketchledge, equalization and regulation in L3 coaxial-cable system, **3410**
Finck, M., and F. Pepping, radio communications on German railways, **210**
Finden, H. J., developments in frequency synthesis, **2376**
Findlay, J. W., moving clouds of ionization in E region, **2310**
Fine, H., theory of radio scattering in randomly inhomogeneous atmosphere, **1468**; variation of field strength over irregular terrain in u.h.f. television band, **1786**
Fine, M. E., vibralloy, a ferromagnetic alloy, **124**; elasticity and thermal expansion of Ge, **2348**
Fine, S., with others, nonlinear filtering and wave-shape multiplexing, **670**
Fink, D. G., synchronization in colour television, **2464**
Finke, H. A., and F. Blecher, wide-band frequency-sweep generator for testing television equipment, **486**
Finlayson, D. M., V. A. Johnson and F. M. Shipley, low-temperature Hall curve for *n*-type Ge. **426**
—— with H. M. Barkla, properties of KH_2PO_4 below Curie point. **2047**
Finn, D. L., approximate determination of arctan ω with a linear electrical network, **3641**
Finzi, L. A., and H. L. Durand, rules of similitude for magnetic-amplifier systems, **334**
—— and G. F. Pittman, Jr, comparison of methods of analysis of magnetic amplifiers, **2910**
—— D. P. Chandler and D. C. Beaumariage, transient response of magnetic amplifiers, **2236**
—— G. F. Pittman, Jr, and H. L. Durand, effective feedback ratio of magnetic amplifiers, **3510**
Firestone, W. L., and J. S. Byrne, reduction of distortion in microwave systems, **2788**
Fischer, D., focusing properties of radially decreasing magnetic field with cylindrical electric field, **1460**
Fischer, F. A., acoustic radiators, absorption surface of, **1220**, directivity and amplitude distribution of, **1221**
Fischer, J., and J. Marshall, Type-6BN6 gated-beam valve as fast coincidence counter. **512**
Fischer, K., dependence of signal/noise ratio of s.w. receivers on input voltage, **2125**
Fisher, D. H., P. A. Segrave and A. J. Watts, design of superheterodyne receiver for television, **1504**
Fisher, F. J., with others, equipment for impedance matching and measurement at v.h.f., **1747**
Fisher, J. F., generation of N.T.S.C. colour signals, **1822**
—— with others, colour characteristics of flying-spot signal generator, **2807**
Fisher, L. H., with G. A. Kachickas, time lags of field breakdown in N_2, **1308**
Fitzosborne, F. J., activation of BeCu multipliers. **1517**
Flammer, C., variational methods for periodic lattices and artificial dielectrics, **2325**
Flanagan, T. P., spurious f.m. in signal generators, **3562**
Flater, E., and K. Fränz, electronic multiplier using modulated pulses, **1417**
Fleischmann, R., and R. Kollath, method for measuring charge of fast electrons. **2957**
Fleisher, H., with L. P. Hunter, graphical anlaysis of transistor switching circuits, **653**
Flesher, G. T., and G. I. Cohn, dielectric loading for waveguide linear accelerators, **2408**
Fletcher, R. C., with H. B. Briggs, new infrared absorption bands of *p*-type Ge, **424**
Flint, H. T., and E. M. Williamson, relation of quantum theory to gravitation and electromagnetism, and application to theory of electron, **3570**
Flood, J. E., time-division multiplex systems, **1793**
Florentin, J. J., with others, temperature variation of magnetization of Ni, **1033**
Floyd, C. F., R. L. Corke and H. Lewis, design of linear-phase low-pass filters, **1614**
Flügge, S., integration of oscillation equations, **1413**
Fogel, H., and S. Napolin, cavity tuner for u.h.f. television, **1506**
Fogelberg, C. V., and others. c.r. tubes with internal pole pieces, **257**
Follingstad, H. G., J. N. Shive and R. E. Vaeger, optical encoder and digit register using transistors, **766, 2373**
Folsom, R. A., Jr, with E. M. T. Jones, circular dielectric-disk aerial, **2572**
Foner, S., Hall effect in Ni ferrite. **1398**
—— and E. M. Pugh, Hall effect of Co-Ni alloys and armco iron, **3625**
Fontaine, J., with L. Lahure, radio equipment and navigation aids aboard ship, **3418**
Ford, G. T., and E. J. Walsh, high-transconductance tubes for broad-band telephony, **293**
Ford, J. R., with others, analysis of microwave-aerial side-lobes, **41, (C)2226**
Forrer, R., effective magnetic distances in metals and alloys, **1393**
Forsberg, N., and P. Isberg, 1-MV van de Graaff generator for ion accelerator, **184**
Forsgren, S. K. H., calculations of ray paths in ionosphere, **3093**
—— and O. F. Perers, recording of rain by radar, **2994**
—— with others, microwave propagation in optical range, **3097**
Forsyth, P. A., radio measurements and auroral electron densities, **1999**
—— B. W. Currie and F. E. Vawter, scattering of 56-Mc/s radio waves from lower ionosphere, **2119**
—— with others, radio reflections from aurora, **3308**
Fowler, C. S., with others, precision phase comparator for l.f., **(A)483, 1080**; measurement of phase velocity of 127·5-kc/s ground wave, **1782**
Fowler, V. J., transmission-line valves, **269**
Fox, A. G., with M. T. Weiss, magnetic double refraction at microwave frequencies, **755**
Frachebourg, C., international Electrical Engineering U.D.C. Committee, Copenhagen 1952, **2191**
v. Fragstein, C., reciprocity of transmission of e.m. waves through multilayered media, **90**
di Francia, G. Toraldo. See Toraldo di Francia, G.
Franck, E. W., with E. Schmidt, manufacture of magnetic recording materials, **2204**
Francken, J. C., and H. Bruining, developments in image iconoscope, **3733**
François, P. A., radio and television at Paris Fair, **3398**
Frank, M., improvements in facsimile equipment, **1492**
Frank, R. L., harmonic-insensitive rectifiers for a.c. measurements, **3662**
Frank, R. W., wide-range pulse generator, **3672**
Frank, V., geometrical arrangement in Hall-effect measurements, **3054**
Frankcom, C. E. N., navigational work in ocean weather ships, **1023**
Franken, B., and others, influence of magnetic field on resistance of Fe films, **1039**
Franklin, A. D., and A. E. Berkowitz, approach to saturation in dilute ferromagnetic materials, **2337**
Franz, H. J., with H. Göttlich, new I.K.A. cables. **617**
Franz, K., with G. Cosci, highly stable power supply, **552**
—— with E. Flater, electronic multiplier using modulated pulses, **1417**
Franz, W., and K. Deppermann, theory of diffraction by cylinder, taking account of surface wave, **1665**
Frazer, B. C., and R. Pepinsky, X-ray analysis of ferroelectric transition in KH_2PO_4, **2048**
Freely, J., with others, mechanism of field-dependent secondary emission, **998**
Freeman, J. J., conductance and noise spectrum of electron streams, **1198**; N.B.S. noise comparator for microwaves, **2081**
Freeman, W. H., with others, wide-band coupling unit for power-line carrier equipment, **359**
Freiesleben, H. C., Decca-chart calculations, **2009**
Fremlin, J. H., noise in thermionic valves. **1864**
Fréon, A., and A. Martin, simple mains-frequency pulse generator, **488**
Freudenhammer, K., output-stage harmonic power radiated by transmitter, **2482**
Frey, J., with J. Brackmann, copper eddy-current losses in coils with ferrite cores. **3526**
—— with others, measurements on high-μ ferrite cores, **1032**
Freymann, M., and R. Freymann, method of studying lattice defects in ZnO. **1700**
Freymann, R., R. Rohmer and B. Hagene, lattice defects and Debye r.f. absorption in iron oxides, **2328, (C)3612**
—— with M. Freymann, method of studying lattice defects in ZnO, **1700**
Friedland, S. S., and H. S. Katzenstein, factors influencing life of self-quenching counters, **2104**
Friedlander, E., new vector slide rule, **2714**

World Radio History

Friedrichs, K. O., quantum theory of fields, **1289, 1290, 2620**
Frigon, A., Radio Canada building in Montreal, **221**
Friis, H. T., with S. A. Schelkunoff, Antennas. Theory and Practice. **(B)637**
Frith, R., with others, humidity of upper troposphere and lower stratosphere over southern England, **1671**
Fritz, K., magnetrons, development in Germany, **2852**, currents and space charge in, **3764**
Fritze, E. H., punched-card-controlled aircraft-navigation computer, **2674**
—— with W. G. Anderson, instrument-approach-system steering computer, **1369**
Fritzsche, C., with others, dependence of low-temperature conductivity of Cu_2O on oxygen pressure, **1385**
Fritzsche, H., effect of dissolved oxygen on conductivity of ZnO, **1031**
Friz, W., with W. Klein, characteristics of travelling-wave valve with dispersive delay line, **2826**
Froelich, H. C., ZnS-Cu phosphors with yellow and red emission, **3609**
Fromageot, A., concept of entropy in calculus of probability, **536**; London conference, Sept. 1952, on applications of theory of information, **3702**
Froula, H., direct measurement of images in electron microscope, **2759**
Frühauf, H., matrix calculus and application of 'normalized magnitudes' in electrical engineering, **3639**
Fründt, H. J., multipath distortion on a f.m. u.s.w. beam link, **218**
Fry, D. W., linear electron accelerator, **507**
Fubini, E. G., and F. H. Rockett, Jr, bandwidth of $\lambda/4$ sections, **30**
Fuchs, G., reflections in coaxial cable due to impedance irregularities, **2730**
Fues, E., with W. Bösenberg, barrier layer of Ge plate rectifier with forward current, **2698**
Fujimura, T., with others, permittivity and permeability of ferrites at 6·6-cm λ, **(C)1401**
Fukuhara, S., with H. Miyazawa, electrolytic conduction in Cs_3Sb, **2676**
Fukushima, N., characteristics of magnetic storm, 3rd Aug. 1949, **2644**; constitution of polar magnetic storms, **2978**
—— and T. Hayasi, relation between F_2-layer disturbance and geomagnetic storminess, **2986**
—— with T. Nagata, constitution of polar magnetic storms, **2977**
Fuller, C. S., and J. A. Ditzenberger, diffusion of Li into Ge and Si, **3616**
—— and J. D. Struthers, Cu as acceptor element in Ge, **119**
Funatogawa, Z., with Y. Gondo, temperature dependence of magnetoresistance of Fe single crystal, **2044**
Furrer, W., and A. Lauber, reverberation-time measurements with warble tones and with white noise, **1571**; 'diffusion' in room acoustics, **1893**
Furutsu, K., calculation of field strength near antipode of transmitting station, **2779**

Gabler, H., G. Gresky and M. Wächtler, accuracy of c.r.o. direction finder, **1367**
Gabor, D., information content of an e.m. signal, **2135**
Gabrysh, A. F., with others, ultrasonic velocity and absorption in air, **7**
Galbraith, R. A., with D. K. Cheng, stagger-tuned multiloop aerials for wide-band l.f. reception, **3207**
Gale, A. J., with E. A. Burrill, electron beams sterilize food, **505**
Galkin, G., G. Dolgikh and V. Yurkov, electrical properties of Sb_2S_3 and Bi_2S_3, **3019**
Gallagher, C. J., plastic deformation of Ge and Si, **1403**
Gamble, M., hermetically sealed Mg-CuS rectifiers, **2153**
Gamo, H., Faraday rotation of waves in round waveguide, **2889**
Gans, F., J. Lagrenaudie and P. Seguin, preparation and properties of arsenide semiconductors, **3325**
Gans, R., and M. Bemporad, theory of straight aerial, **2220**
Garbuny, M., theory of reflex resnatron, **1207**
Garin, P., with —— Prugne, use of membranes in vacuum technique, **110**
Garratt, G. R. M., and A. B. Mumford, history of television, **848**
Gässler, G., with E. Zwicker, suitability of dynamic headphones for measurements on f.m. tones, **312**
Gaume-Mahn, F., ferromagnetism of Gd-Mg alloys, **127**
Gautier, P., measurement of derivatives of axial field of powerful magnetic lens, **185**
Gauzit, J., temperature and photochemical phenomena in upper atmosphere, **1344**
Gavin, M. R., transit-time oscillations in triodes, **(D)1200**
Gavreau, V., and A. Calaora, absolute calibration of microphones, **3173**
Gayffier, A., with P. Giroud, developments of Decca navigation system, **3313**
Gea Sacasa, R., can prediction be simplified? **1107**; ionospheric propagation, **1773**; predictions of optimum working frequency, **3689**
Gebauer, R., and H. Kosmahl, construction, properties, operation and applications of klystrons, **596**
Geddes, W. K. E., with P. E. Axon, calibration of disk recordings by light-pattern methods, **2875**
Gee, C. C., electron tubes for industry and research, **587**
van Geel, W. C., with J. W. A. Scholte, impedances of electrolytic rectifier, **2801**
van Geen, J., vectorial c.r.o. display of sinusoidal voltages, **3372**
Geiger, R. H., with others, microwave determination of electron density and collision frequency in gas discharge, **380**
Geiling, L., matching of thermocouple and galvanometer, **2387**
Geisler, A. H., with D. L. Martin, permanent-magnet properties of Co-Pt alloys, **(D)2709**
Geist, D., and K. Seiler, temperature dependence of backward current in Ge p-n junctions, **423**
—— with others, thermally produced lattice defects in Ge, **1697**
Genna, W. N., with W. R. H. Lowry, independent-sideband s.w. receiver, **2425**
Gens, R. S., with H. L. Rorden, radio noise in relation to design of h.v. transmission lines, **927**
Gent, A. W., transient response of r.f. and i.f. filters to a wave packet, **(A)350, 983**
Genzel, L., and H. Müser, photoelectric and optical properties of PbS layer, **2677**
George, S. F., with A. H. Schooley, signal/noise characteristics of detectors, **529**
George, T. S., and H. Urkowitz, noise in microwave superregenerative amplifier, **1948**
Gerber, E. A., measuring constants of piezoelectric vibrators, **3670**
Gerhardt, J. R., with C. M. Crain, rapid variations of microwave refractive index of air, **431**
—— with others, measurement of tropospheric index-of-refraction fluctuations and profiles, **1341**
Gerhold, R. A., printed circuits and the automatic factory, **3548**
—— with S. F. Danko, printed circuits for transistors, **674**
Gerjuoy, E., reflection of waves from a point source, **2540**
Gerlach, A. A., test-pulse generator for digital computers, **489**
—— with others, electronic function generator, **451**
Gerlach, W., coercive force and crystal energy, **753**
Germain, P., development of a product integrator, **149**
Gershman, B. N., pulse distortion in ionospheric propagation, **513**
Gerspacher, F., ignitron-type timer for spot-welding machines, **501**
Gerst, I., with A. D. Fialkow, maximum gain of RC network, **1606**
Gerstman, L. J., with others, experiments on synthetic speech sounds, **919**
Gertsenshtein, M. E., longitudinal waves in plasma, **1310**
Gevers, M., with others, measurement methods for properties of ferroxcube materials, **3060**
Geyger, W. A., magnetic amplifiers, balance-detector type, **3504**, self-balancing potentiometer type, **3511**
Ghosh, M., increase of F_1 and F_2 ionization from sunspot minimum to maximum, **1993**
Giacoletto, L. J., parallel tuned circuit periodically switched to d.c. source, **65**; junction-type transistor, equivalent circuits for, **644**, characteristics at l.f. and m.f., **2489**, equipment for measurement of admittance parameters in range 1 kc/s–1 Mc/s, **3359**; linear four-terminal networks including transistors, **2238**
—— and H. Johnson, u.h.f. triode design, **1536**
Giacomini, A., ultrasonic measurements, **1561**
Giambomi, L. A., with S. J. Barnett, new gyromagnetic effect in permalloy and iron, **757**
Gianola, U. F., magnetic lenses with axial field γ/z^n, **189**
Gibbons, J. J., and R. J. Nertney, wave-equation solutions for ionospherically reflected long waves, **(D)410, 517**
—— and R. L. Schrag, solving wave equation for region of rapidly varying refractive index, **803**
—— R. L. Schrag and A. H. Waynick, long-delay ionospheric echoes at 150 kc/s, **1992**
Gibson, A. F., with R. Lawrance, measurement of drift mobility in semiconductors, **1379**
Gibson, J. W., and C. F. Miller, electric strength of SF_6 at r.f., **3627**
Gibson, W. T., thermistor manufacture, **2240**
de Gier, J., and others, steel c.r. tube for television receivers, **3132**
Gieseke, W., with others, measurements on high-μ ferrite cores, **1032**
Gihring, H. E., with others, multiple television and f.m. aerial system, **1589**
Gilbert, M., with others, fundamental aspects of colour television, **1814**
Gilbert, R. W., induction galvanometer as converter, **3666**
Gilford, C. L. S., membrane sound absorbers in broadcasting studios, **924**
—— with T. Somerville, composite c.r.o. displays of acoustic phenomena, **307**
Gillam, C., with others, B.B.C. television transmitting aerials, **934**
Gille, J. C., airborne servomechanism discriminators, **3422**
Gillies, A. W., electrical oscillations, **2264**
Gilling, B. T., flywheel synchronization, **1499, 3738**
Ginzton, E. L., with others, debunching of electron beams constrained by strong magnetic fields, **3459**
Gipps, G. de V., with others, ionosphere measurements at oblique incidence over eastern Australia, **807**
Giroud, P., and A. Gayffier, developments of Decca navigation system, **3313**
Gialianelli, R. M., with M. J. Kirby, stability of varying-element servomechanisms, **3723**
Giustini, S., approximate formulae for gain of directive aerial, **635**
Glauberman, A. E., and A. F. Lubchenko, dielectric properties of $BaTiO_3$, **3011**
Gledhill, G. A., with P. E. Ackland-Snow, 6-waveform generator and display unit for testing television channel, **1087**
Glinz, C., field-strength fluctuations of Swiss broadcasting stations, **2424**
Gluck, S. E., EDVAC, **2060**
Gobrecht, H., and F. Speer, measurement of secondary emission, **3581**
Godoli, G., with G. Righini, solar influence in gyro-interaction experiments, **3693**
Gohar, M. K., with A. E. S. Mostafa, determination of parameters of single-layer coils, **1922**
Golay, M. J. E., correlation $v.$ linear transforms, **1477, (D)3701**
Goldberg, C., acceptors produced in Ge by quenching, **1407**
Goldberg, E. A., high-accuracy time-division multipliers for analogue computers, **151**
Goldberg, J. L., with others, u.h.f. cable measurement equipment, **2393**
Golden, N., and R. Nielsen, c.r.o. for display of static characteristics of transistors, **784**
Golden, R. K., with A. Baños, Jr, e.m. field of rotating magnetized sphere, **1334**
Goldsmith, P., with E. A. Roberts, piezoelectric crystals for pressure, temperature and humidity measurements, **2103**
Goldstein, A., h.f. dielectric heating, **1453**

World Radio History

Goldstein, L., and M. A. Lampert, new linear passive nonreciprocal microwave circuit component, **1265, 3232**
—— J. M. Anderson and G. L. Clark, interaction of microwaves in gas-discharge plasma, **2637, 2970**
—— M. A. Lampert and R. H. Geiger, microwave determination of electron density and collision frequency in gas discharge, **380**
Gondesen, K. E., conference on magnetic sound recording, **1577**
Gondet, H., rotating-iron magnetometer, **1730**
Gondo, Y., and Z. Funatogawa, temperature dependence of magnetoresistance of Fe single crystal, **2044**
Good, E. F., *RC*- or direct-coupled power stage, **1286**
Goodchild, C. W., and R. C. Looser, measurement of phase delay in television transmission circuits, **1750**
Goodell, C. E., ultrasonic recorder for torpedo depth, **1447, 2401**
Goodell, J. D., and T. Lode, multistable magnetic digit-storage devices, **449**
Goodfriend, L. S., bypass and decoupling circuits in audio design, **2614**
Gorbacheva, N. A., with others, thermo-luminescence of sulphate-base materials, **3006**
Gordon, D. S., vibration measurements, **(D)2400**
Gordon-Smith, A. C., 600-Mc/s field-strength meter, **156**
Gordy, W., with W. C. King, spectroscopy at 1–2-mm λ, **2823**
—— with others, line breadths of the microwave spectrum of O_2, **91**
Goret, R., standardization and telecommunications, **2526**
Gorodetski, P. G., transient phenomena in oscillatory circuit with variable inductance, **3551**
Gorter, E. W., with others, preferred crystal orientation in ferromagnetic ceramics, **1036**
Gossard, E. E., with L. J. Anderson, field-strength prediction for nocturnal duct, **1112**
Gosslau, K., precision frequency measurements, **1039**
Gütlich, H., and H. J. Franz, new I.K.A. cables, **617**
Götze, W., tunable *RC* network with one variable element, **958**
Goubau, G., with C. E. Sharp, u.h.f. surface-wave transmission line, **930**
Goucher, F. S., and M. B. Prince, current amplification factor for *p-n*-junction transistors, **2488**
Goulding, F. S., voltage stabilizer with cold-cathode triode, **554**
Goundry, R. A., with W. K. Squires, constant-input-impedance second detector for television receivers, **254**
Gourceaux, M., and A. Colombani, currents induced in wide conductor by narrow conductor carrying h.f., **81**
—— with A. Colombani, h.f. resistance of conducting strip parallel to conducting plane, **80**
Gouriet, G. G., spectrum equalization, **1936**
—— with E .C. Cherry, compression of television signals by recoding, **1154**
Gozzini, A., dielectric constants of gases at cm λ, **1083**
Grace, A. C., and J. A. Lane, direct-reading standing-wave indicator, **3066**
Grachev, A. A., space correlation of noise of magnetic reversals, **3029**
Graf, L., H. R. Lacour and K. Seiler, plastic deformability of Ge, **2033**
Graffunder, W., with H. Briner, geometrical transformation of impedance diagrams, **2576, (C)3494, 2907**
Graham, R., Jr, with A. A. Meyerhoff, fixed-length transmission lines as circuit elements, **1272**
Graham, R. S., with J. W. Rieke, television terminals for L3 coaxial-cable system, **3424**
Granier, J., electrical properties of rubber, **2035**
Granovski, V. L., theory of plasma with variable current, **386**
Granville, J. W., and W. Bardsley, properties of Si point-contact transistors, **2822**
—— and H. K. Henisch, large-area contacts on Ge, **118**
—— H. K. Henisch and P. M. Tipple, contact properties of *p*-type Ge, **117**
Gratama, S., noise in receivers and amplifiers, **815**
Grattidge, W., and H. John, electronic properties of BaS, **893**
Gray, D. J., V. P. Gurske and W. E. Morrow, wide-band data transmitter, **3559**
Grayson, H., with others, circuit technique for f.m. microwave links, **220**
Graziadei, H., frequency-independent transition between coaxial cable and balanced line, **3478**
Greefkes, J. A., with others, delta modulation, **543**
Green, E., television modulation, **(D)1163**; exact amplitude/frequency characteristics of ladder networks, **1267**
Green, M. W., with others, two new photomultipliers for scintillation counting, **266**
Greenberg, H., and D. R. Meierdiercks, ground-reflection phase-error characteristics of vertical aerial, **2221**
Greenblatt, M. H., and others, two new photomultipliers for scintillation counting, **266**
Greene, F. M., influence of ground in v.h.f. field-strength measurements, **2389**
Greenhalgh, J., single-valve line timebase, **2814**
Greenhow, J. S., with T. R. Kaiser, decay of radio echoes from meteor trails, **1978**
Greenwald, C., with others, counter-circuit multiplex receiver, **3099**
Greenwald, S., antiferromagnetic structure deformations in CoO and MnTe, **3035**
Greenwood, N. N., with J. S. Anderson, semiconducting properties of Cu_2O, **1701**
Gresky, G., with others, accuracy of c.r.o. direction finder, **1367**
Gressmann, R., and K. H. Kaltbeitzer, determination of service area for planning u.s.w. networks, **213**
Grieg, D. D., and H. F. Engelmann, microstrip for kMc/s range, **621, 2212**
Griffin, J. P., high-stability 100-kc/s crystal frequency standards, **1083**
Griffing, G., with D. R. Bates, scale-height determinations and aurorae, **3309**
Griffith, G. W. S., measurement of nonlinearity in television links, **1084**
Griffiths, E., portable p.a., **1899**
Griffiths, H. D., waveguide arrays with symmetrical conductance functions, **2903**
Grifone, L., omnidirectional reflectors for microwaves, **1684**
Grillini, L., experiment with microwave diffraction grating, **1246**
Grillot, E., and P. Guintini, infrared photoluminescence of CdS-Cu, **2012**
Grim, W. M., and A. B. Van Rennes, effects of grid/cathode capacitance in pulse-height selectors, **941**
Grimsdell, G., characteristics of miniature voltage-regulator discharge tubes, **(D)267**
Griswold, W. R., with E. J. Isbister, harbour radar at Boston, Long Beach, New York and Liverpool, **1685**
Groendijk, H., with others, Type E80T valve, synchronization of v.f.o. with, **2816**, multichannel I.G.O. circuits using, **2817**; rubber-membrane model for electron paths, **3756**
Groll, H., power measurement with thermistors at h.f., **1441**
Gross, B., linear networks, **2245**
Grosser, H., with J. W. Cohen, calculation of leakage flux of pendent-armature relays, **387**
Grosskopf, H., input resistance of capacitor microphone, **(D)16**; methods of directional sound reception, **1574**
Grosskopf, J., determination of transmitter service area under conditions of interference, **214**; reflectometer for measurements in s.w. range, **477**
Grossman, A. J., with others, L3 coaxial-cable carrier system, **3409**
Groves, W. E., transmission of e.m. waves through pair of parallel-wire grids, **3590**
Gruen, W. J., theory of a.f.c. synchronization, **3214, (C) 3524**
Gruenberg, H., second-order beams of slotted-waveguide arrays, **1914**
Grümm, H., spreading of focused electron beam due to electron charge, **2962**
Grützmacher, M., Physikalisch-Technische Bundesanstalt, Brunswick, **2**
Guanella, G., F. Jenny and P. Waldvogel, Swiss developments in h.f. technology, **1548**
Gubanov, A. I., theory of contact, between metal and semiconductor, **379**, between two semiconductors, **2687**; solid rectifiers, theory of, **2038**, dynamical theory of, **3630, 3631**
te Gude, H., triple-diode triode Type-E/U/PABC 80, **1191**
Guénard, P., and H. Huber, interaction of space-charge waves in crossed magnetic and electric fields, **1526**
—— with others, amplification by space-charge waves, **278**, oscillations in whole-anode magnetron related to, **904**
Guertler, R., folded dipoles with two or more elements, **1234**
von Gugelberg, H. L., cold-cathode valves, **2501**
Guggenheim, E. A., electron spin in semiconductors, **1960**
Guilion, H., ensuring stability and equality of channel widths in pulse-amplitude analyser, **2230**
Guintini, P., with E. Grillot, infrared photoluminescence of CdS-Cu, **2012**
Guittard, J., analysis of air vibrations in pipes with discontinuities, **599, 2193**
Gundert, E., trapezoidal distortion in c.r.o. tubes, **2742**
Gungle, W. C., with others, electroluminescence, **2956**
Gunn, J. B., resistance of Ge contacts, **1030**; radiative transitions in Ge, **2331**
Gunn, W. F., e.m. surface waves, **620**
Gunn-Russell, C., with R. W. Leslie, remote control and automatic monitoring of Third Programme transmitter, **261**
—— with others, B.B.C. monitoring technique for unattended transmitters, **548**
Günther, G., coaxial cables with disk insulators at frequencies > 1 kMc/s, **3183**
Günther, J., synchronization technique in television, **1153, (C)2161**
Guptill, E. W., sound field, near circular transducer, **913**, of piston source, **1876**
Gurevich, S. B., and V. G. Panchenko, ferroelectric materials, **1373**
Gurske, V. P., with others, wide-band data transmitter, **3559**
Gutbier, H., with H. Neuert, counter tubes with Ar and methylene-halide filling, **1461**
Gutterman, A., with B. J. O'Neill, equipment for transistor testing, **3053**
Guy, R. F., with others, multiple television and f.m. aerial system, **1589**

Haacke, W., stability criterion for *n*-mesh varying-parameter networks, **1271**
de Haan, E. F., with J. G. van Wijngaarden, l.f. noise in electrometer valves, **1185**
Haantjes, J., with others, effects due to curvature of valve characteristics, **1854**; new trends in a.m./f.m. receiver design, **2427**
Haas, G., direct-voltage amplifier with crystal contact breaker, **2395**
Haase, K. H., filters, fundamentals of theory and technique, **665**, coupling-free, systematic design procedure for, **1612**
Hadley, C. P., thermionic emission from oxide-coated W filaments, **1857**
Hadley, D. T., with others, aerial-radiation-pattern analogue computer, **3198**
Hadley, L. N., with K. K. Curtis, acoustical interference filters, **912**
Haeff, A. V., with others, resistive-wall amplifier valve, **3147**
Haenny, C., with R. Favre, construction of Maze-type counters, **2106**
Hafner, E., e.m. oscillations, of a biaxial anisotropic parallelepiped, **1315**, of a uniaxially anisotropic cavity resonator, **1623**; dielectric constant of uniaxial crystals, **2382**
—— with F. Reder, method of determining dielectric constants of fluids at cm λ, **1734**
Hagedorn, R., statistical model of $BaTiO_3$ single crystal, **1043**
Hagen, C., with others, variation of partial processes in magnetostriction, **130**
Hagen, J. P., and N. Hepburn, solar outbursts at 8·5-mm λ, **93**
Hagenberg, T., with others, steel c.r. tube for television receivers, **3132**
Hagene, B., with others, lattice defects and Debye r.f. absorption in iron oxides, **2328, (C)3612**
Hagenhaus, K., rectifier-type voltmeter and distortion meter without valves, **167**

World Radio History

Hahn, M., with F. Lenz, asymmetry of magnetic electron lenses, **2098**
Hahnel, A., multichannel crystal control of oscillators, **975**
Halacsy, A. A., calculation of magnetizing force, **3587**
Halbach, K., design of linear networks with optimum signal/noise ratios, **1927**
Halford, G. J., wide-band waveguide phase-shifter, **2567**
Hall, C. M., variable equalizer for broadcast-programme circuits on trunk lines, **820**
Hall, E. L., world-wide reception of standard-frequency broadcasts, **522**
Hall, G. L., with others, positive and negative ions in c.r. tubes, **2846**
Hall, G. N., with C. L. Rouault, h.v. medium-power p-n-junction rectifier, **835**
Hall, H. H., with others, reverberation-room measurements of loudspeaker efficiency, **2873**
Hall, J. S., distant field of nonresonant sloping-V aerial, **3205**
Hall, R. N., p-n junctions produced by growth-rate variation, **743**; power rectifiers and transistors, **834**
Hallows, R. W., reactivation of dry cells, **3117**
Halpern, L., and K. M. Koch, Corbino effect and magnetic variation of resistance in Bi, **1710**
Halsey, R. J., and H. Williams, Birmingham/Manchester/Holme-Moss television cable system, **1147**
Halter, J. B., with J. G. Woodward, lateral mechanical impedance of gramophone pickups, **3181**
Hamaker, H. C., theory of sequential sampling for attributes, **2715**
Hamer, E. G., v.h.f. radio, **547**; v.h.f. radio noise, **817**; noise performance of v.h.f. receivers, **1789**; v.h.f. aerial radiation measurements, **3480**
—— and D. W. Elson, a.f. combining system for space-diversity receivers, **2426**
Hamilton, G. E., and R. Howite, grey-scale generator, **565**
Hammett, M. G., and H. W. Finch, β-particle and γ-ray thickness gauges, **496**
Hamming, R. W., with R. M. Bozorth, magnetostriction constants of single crystals, **2045**
Hammond, P., power gain of aerial arrays, **1909**
Hammond, P. H., with F. J. U. Ritson, electronic simulator for hydraulic servomechanism, **1054**
Hampe, W., with M. L. Exner, determination of damping of pulsating air bubbles in water, **2534**
Hampikian, A., analogue computer for magnetic electron lenses, **2722**
Hancock, E. J., photoformer design and performance, **452**
Handler, W., and J. Peters, calculation of transients in carrier-current systems, **2246**
Hanle, W., and K. H. Rau, light emission and destruction of phosphors by electron and ion impact, **734**
Hannahs, W. H., and J. W. Eng, production control of printed resistors, **47**
—— and N. Stein, printed unit assemblies for television, **352**
Hansen, G., transmitting equipment at Wavre-Overijse broadcasting centre, **1128**
Hansen, J. E., a.f. impedance and phase-angle meter, **2741**
Hansford, R. F., and G. J. Dixon, remote display of radar pictures, **2005**
Harang, L., and B. Landmark, 35- and 74-Mc/s pulse echoes observed during aurorae and geomagnetic storms, **2976**
Hardeman, G. E. G., with N. J. Poulis, temperature dependence of spontaneous magnetization of antiferromagnetic single crystal, **3336**
Harden, B. N., diffraction of e.m. waves by half-plane, **88**
Harder, E. L., power control with magnetic amplifiers, **176**
Hardie, A. M., mechanical synthesis of a.m. wave, **469**; equivalent cathode diameter for squirrel-cage filament structures, **3153**
Harding, K. C., with C. R. Knight, specifications for reliable valves, **270**
Hardy, H. C., H. H. Hall and L. G. Ramer, reverberation-room measurements of loudspeaker efficiency, **2873**
Harley, H. V., valve matching using resistors, **3563**
Harmuth, H., gas-filled counter and switching valves, **296**
Harnischmacher, E., improvements to Berkner-Wells-Seaton-type ionosphere sounder, **725**
—— and K. Rawer, radio links covering very great distances, **520**
Harrington, R. F., field of current element near edge of conducting half-plane, **2967**
Harris, E. F., helical beam aerial, for citizens' radio, **1593**, performance of, **3489**; u.h.f. mobile aerial array, **2222**; experimental investigation of corner-reflector aerial, **2224**
Harris, H., Jr, M. J. Kirby and E. F. von Arx, servomechanism transient performance from db/log-f plots, **3721**
Harris, H. C., a.m.-f.m. analogy, **3246**
Harris, I. A., transit-time oscillations in triodes, **(D)1200**
Harris, J. N., precision 1-MΩ h.v. ratio box, **474**
Harris, J. R., transistor shift register and serial adder, **767**
Harsh, M. D., with others, improved 'graphechon' storage tube, **1539**, **2845**
Hart, R. C., life testing of c.r. tubes, **1444**
't Hart, L., and C. Strässer, modern transmitting equipment for merchant ships, **2818**
Hartel, W., electronic voltage stabilizer, **1804**
Hartmann, W., properties of capacitors at h.f., **2244**
Hartsfield, W. L., and R. Silberstein, comparison of c.w. field intensity and back-scatter delay, **808**
Hartshorn, L., units and standards of electrical measurement, **1059**
Hartwright, J. F., operation of television outside-broadcast units, **1144**
Harvey, A. F., instruments for microwave measurements, **(D)3362**
Harvey, P. J., television booster stations, **1811**
Hasegawa, M., and H. Maeda, conductivity of upper atmosphere deduced from variations of geomagnetic field, **2647**
Hasselbeck, W., measurement-instrument error, **1074**
Hastings, A. E., methods of obtaining frequency spectra, **160**
—— and J. E. Meade, device for computing correlation functions, **161**
Hastings, J. M., with others, neutron diffraction study of Mg ferrite, **3335**
Hatanaka, T., and F. Moriyama, characteristics of noise storms, **2971**
Hatfield, P., with R. G. Patton, ultrasonic applications in rubber industry, **493**
Hathaway, J. C., with M. L. Doelz, electromechanical i.f. filters, **1615**
Hatta, T., with Y. Nomura, theory of linear aerial, **3201**
Hausman, H. J., with others, r.f. power supply, **1134**
Hausner, H. H., world congress on powder metallurgy, **1412**
Haven, Y., and J. H. van Santen, pre-exponential factors in formulae for ionic conductivity in solids, **3578**
Hawkins, G. S., and M. Almond, radar observations of major night-time meteor streams, **108**
Hawthorn, A. N., and S. W. Messent, laminated plastic insulating materials, **2353**
Hay, H. G., and R. S. Unwin, tropospheric wave propagation in duct of nonuniform height, **1471**
Hayashi, C., forced oscillations with nonlinear restoring force, **1940**; nonlinear periodic oscillations, stability investigation of, **2361**, subharmonic oscillations in, **2953**
Hayasi, T., with N. Fukushima, relation between F_2-layer disturbance and geomagnetic storminess, **2986**
Haydon, S. C., with others, time lags in electrical breakdown of gases, **3262**
Hayes, E. W., B.B.C. mobile television transmitters, **3127**
Hayes, J. E., television facilities of the Canadian B.C., **1170**
Hayes, M. E., with others, phosphor-photocell radiation detector, **1103**
Haynes, H. E., new principle for electronic volume compression, **965**
Haynes, J. R., and J. A. Hornbeck, temporary traps in Si and Ge, **2691**
Hazard, C., with R. H. Brown, r.f. radiation from supernova (A.D. 1572), **95**
Head, J. W., decomposition of functions, **763**; effect of wall shape on decay of sound in a room, **2872**
Heaps, S. N., with others, instrumentation for geophysical exploration, **2749**
Heavens, O. S., contamination of evaporated Ag and Ge films by heater material, **758**
Heber, G., quantum theory of ferromagnetism, **2340**; structure of ferromagnetic state in α-Fe and some Fe alloys, **3027**
Heddle, T. A., temperature sensitivity of special magnetic materials, **3338**
Heiland, G., and G. Rupprecht, logarithmic-scale valve galvanometer, **3363**
Heim, T., electrical microdynamometer, **490**
Heller, D. M., choice of channel spacing in mobile-communication bands, **3714**
Hellerman, H., and C. R. Cahn, linear detection of a.m. signals, **208**
Hellgren, G., propagation of e.m. waves along conical helix, **1973**
—— and J. Meos, location of aurorae with 10-m radar equipment, **728**
Helliwell, R. A., graphical solution of sky-wave problems, **1469**
Hellstrand, E., with others, synchronization of pulsed high-energy ion beams, **1448**
Helwig, G., conductivity and structure of sputtered CdO layers, **133**
Henderson, C., F. F. Heymann and R. E. Jennings, phase stability of electron cyclotron (microtron), **2090**
Henisch, H. K., with J. W. Granville, large-area contacts on Ge, **118**
—— with others, contact properties of p-type Ge, **117**
Henniger, H., eddy-current losses in ferromagnetic materials with complex conductivity, **1400**
Henning, R. E., with A. L. Witten, wide-band waveguide recording reflectometer, **468**
Henry, E. C., with J. R. Hensler, resistance of refractory oxides at 600–1500°C, **2684**
Henschke, R. A., matrix analysis of transmission through multilayer dielectric wall, **1668**
Hensler, J. R., and E. C. Henry, resistance of refractory oxides at 600–1500°C, **2684**
Hensley, E. B., electrical properties of porous semiconductors, **737**
Hepburn, F., and E. T. Pierce, atmospherics with very-low-frequency components, **2771**
Hepburn, N., with J. P. Hagen, solar outbursts at 8·5-mm λ, **93**
Hepp, G., battery-operated G-M counter, **3682**
Herbert, R. J. T., discrimination against noise in scintillation counters, **191**
Herbstreit, J. W., signal-generator method for measurement of low signal levels, **1061**
—— with others, ground-to-air cochannel interference at 2·9 kMc/s, **1798**; v.h.f. transmission over mountainous paths, **3396**
Hercock, R. J., and D. M. Neale, exposure timers compensated for supply-voltage variations, **789**
Hergenrother, R. C., and A. S. Luftman, improved single-gun storage c.r. tube, **1868**
—— and H. G. Rudenberg, direct-reading oscilloscope for 100-kV pulses, **3067**
Heritage, R. J., and J. R. Balmer, metallizing glass, ceramic and plastic surfaces, **2346**
Herman, E. B., with others, analysis of microwave-aerial side-lobes, **41**, **(C)2226**
Herman, F., and J. Callaway, structure of Ge crystal, **1699**
Hermann, R., bibliography on metre waves in mobile services, **3407**
Herpin, A., with C. Dufour, propagation of e.m. waves in transparent periodically stratified medium, **3589**
Herreng, P., G. Couanault and G. Plottin, 3 signal generators covering range 20–1200 Mc/s, **1084**
Herrick, J. F., and F. H. Krusen, physiological effects of microwaves, **2748**
Hersperger, S. P., with W. J. Kessler, recent developments in radio location of thunderstorms, **1020**
Hersping, A., measurement of constants of ferrites with slotted coaxial line, **1742**
Hertel, P., Jr, A. W. Straiton and C. W. Tolbert, dielectric-constant measurements at λ 8·6 mm, **3655**
Hertwig, H., automatic tuning control of h.f. generators with varying load, **681**

World Radio History

Hertz, C. H., ferromagnetic scaling circuit, 1255
Herwelly, A., luminescence of phosphors in electric fields, 1644
Herzog, G. B., with others, c.r. tube plots transistor curves, 1437; transistor circuits for television, 2813
Herzog, W., transistor, oscillators, 678, circuits, 1287; methods of improving frequency stability of oscillators, 1513
Heuser, H., organization and installations of Lichow radio station, 2444
Heusinger, P. P., measurement of temperature dependence of velocity of sound in liquids, 1224
Hewel, H., problems of television pickup technique, 1165
Hewish, A., investigation of ionospheric irregularities by observation of diffraction pattern of galactic r.f. waves, 722
Hewitt, W. H., with others, modulators and gyrators using Hall effect in Ge, 1930
Heymann, F. F., with others, phase stability of electron cyclotron (microtron), 2090
Heyn, F. A., and J. J. Burgerjon, synchrocyclotron at Amsterdam, 3076
Heywang, W., stray capacitance with high-μ dielectrics, 3217
Hibbard, L. U., and D. E. Caro, instantaneous measurement of rapidly varying frequency, 1428
—— with D. E. Caro, wide-range oscillator of high stability, 1628
Hibberd, F. H., transient effects in thermionic filaments, 282
Hibi, T., and K. Ishikawa, spectral dependence of thermionic emission from (Ba-Sr)O cathodes, 284
Hiedemann, E., and R. D. Spence, coherent theory of relaxation phenomena, 694
Higgins, T. J., and D. K. Reitan, capacitance calculation for circular annulus by subarea method, 2302
—— with J. van Bladel, e.m.-wave propagation in layered-dielectric waveguides, 321
—— with W. B. Swift, e.m. propagation in waveguides of rhombic cross-section, 2883
Hilgenberg, O. C., meaning and purpose of U.D.C. system, 2520
Hill, A. V., Brownian fluctuations of coupled galvanometer system, 2077
—— with others, moving-coil galvanometer of extreme sensitivity, 2076
Hill, R. D., Jr, with B. G. Bromber, reliability of airborne electronic components, 1939
Hill, S., speech-input systems for broadcasting transmitters, 824
Hillier, G. H., clavioline, 318
Hinchliffe, J. D. S., with others, factors affecting performance of coaxial cables for television links, 928; u.h.f. cable measurement equipment, 2393
Hindman, J. V., with W. N. Christiansen, 1·42-kMc/s emission from galactic hydrogen, 718
Hines, C. O., higher-order approximations in ionospheric wave propagation, 2108; generalized magneto-hydrodynamic formulae, 2636; wave hypothesis of moving irregularities in ionosphere, 2655; reflection of waves from varying media, 2765
Hines, H. M., and J. E. Randall, possible dangers in industrial use of microwave radiation, 1093
Hinton, W. R., measurement of 'A'-matrix elements of passive networks, 1605, (D)3227
von Hippel, A., piezoelectricity, ferroelectricity, and crystal structure, 699
Hirashima, M., motion of electrons in retarding-field valves, 3157
Hirone, T., and others, a.c. magnetization characteristics of a perminvar wire, 2703
Hitchcox, G., electronic instrumentation for pH measurement, 3683
Hitschfeld, W., with others, scattering and attenuation by nonspherical atmospheric particles, 2314
Hobart, T. D., U.S. Navy 1-MW v.l.f. transmitter, 821
Hoerter, G., telecommunications in civil aviation, 3419
Hoffmann, B., energy momentum tensor in Dirac's new electrodynamics, 1298
van Hofweegen, J. M., R/T equipment for Eindhoven-Tilburg link, 546
Hogan, J. T., tuning stability abac, 954
Hogarth, C. A., transistor action, in PbTe, 1409, in PbS, 2036
Hogg, D. C., e.m. field in circular aperture due to spherical waves, 1667
Hohler, G., Dirac's new theory of electrons, 990
Hok, G., statistical approach to space-charge distribution in cut-off magnetron, 592; waveguide-loaded resonator for interdigital magnetron, 2848
—— N. W. Spencer and W. G. Dow, dynamic probe measurements in ionosphere, 3291
Holbrook, J. G., null characteristics of rotating Adcock system, 2906
Holland, E. O., with A. J. Biggs, British television receiver, 1495
Holle, W., and G. Latzel, reciprocity calibration of capacitor microphones, 2544
Hollinghurst, F., and D. S. Tod, specification and testing of television wire-broadcasting systems, 1755
Hollis, J. L., avoiding grid current in class-B modulators, 3249
Hollmann, H. E., nonlinear h.f. and l.f. circuit elements, 645; transistor circuits and theory, 3520; frequency feedback, 3549
Hollway, D. L., optimum space-charge-controlled focus of electron beam, 901; decimal counter tube, 2515
—— and G. J. A. Cassidy, equipment for dielectric measurements at 100–300 Mc/s, 481
Holman, F. S., with O. G. Villard, Jr, electrically tuned RC oscillator or amplifier, 1638
Holman, H. E., and W. P. Lucas, continuous-motion system for televising motion-picture films, 851
Holmes, D. K., energy levels in Si, 421
Holt, R. B., with others, measurement of small-signal parameters of transistors, 3358
Holton, P., and J. Sharpe, corona-stabilized h.v. supply for proportional counters, 1803
Hölzler, E., and H. Holzwarth, 24-channel p.p.m. beam R/T system, 822
Holzwarth, H., comparison of modulation methods for directional radio links, 2791
—— and W. Arens, modulation equipment for 24-channel p.p.m. beam R/T system, 822
—— with E. Hölzler, 24-channel p.p.m. beam R/T system, 822
Hönl, H., and A. W. Maue, uniqueness of solutions in rigorous theory of diffraction, 373
—— and E. Zimmer, intensity and polarization of e.m. waves diffracted at slit, 3269
Honnell, P. M., transmission matrix stability criterion, 2231
—— and R. E. Horn, resonance characteristics by conformal mapping, 53
Honoré, E., and É. Torcheux, Rana radio-navigation system, 3314
Hopf, D., and H. Bock, circuit technique of new valves for a.m./f.m. receivers, 204
Hopkin, A. M., phase-plane analysis of saturating servomechanisms, 2447
Hopkins, F., with others, synthesis of 3-terminal RC networks, 656
Hopkins, H. G., direction finders, (D)2008
Hopkins, H. H., 5 : 1 zoom lens for television, 849
Hopkins, R. U. F., with others, propagation phenomena on microwave line-of-sight links, 1785
Horiuchi, K., surface-wave propagation over curved conductor, 3473
—— with M. Namiki, transient phenomena in waveguide, 2216
Horn, R. E., with P. M. Honnell, resonance characteristics by conformal mapping, 53
Hornbeck, J. A., with J. R. Haynes, temporary traps in Si and Ge, 2691
Hornbostel, W. G., with M. C. Elliason, acoustic firing-error indicator, 192
Horner, F., effect of buried cables on accuracy of d.f. bearings, 2997
Hornfeck, A. J., and G. R. Markow, multiplex telemetry system using teletype transmission, 1097
Horstman, C. C., improvements in core materials for small transformers, 761
Horton, C. E., u.h.f. grounded-grid amplifier, 1205
Horton, C. W., diffraction of plane sound wave by paraboloid of revolution, 3169
Horton, W. F., magnetic amplifiers for industry, 945
—— with J. T. Carleton, figure of merit of magnetic amplifiers, (A)2580, 2912
Hosler, W. R., with R. G. Breckenridge, TiO_2 rectifiers, 229
Hough, J. M., with others, dielectric constant of water films, 1040
Houldin, J. E., impedance-measurement equipment for range 50–500 Mc/s, 478
—— and G. T. Thompson, h.f. bridge with variable ratio arms, 1433
Howard, L. N., and J. S. Smart, specific heat discontinuity in antiferromagnets and ferrites, 3623
Howard, R. C., C. J. Savant and R. S. Neiswander, linear-to-logarithmic voltage converter, 3042
Howard-Flanders, P., focusing system for linear particle-accelerator, 1099
Howe, J. P., properties of graphite, 1411
Howerton, H. K., with others, portable 250-kV accelerators, 3679
Howes, J. W., characteristics and applications of thermistors, 3215
Howitt, G., evaluating a.f.c. systems for television receivers, 570
Hoyaux, M., with others, electronic tachometer, 2747
Hsu, H., transformations of linear active networks, 956
Hubbard, J. C., with others, ultrasonic velocity and absorption in air, 7
Hubbard, W. M., with others, permanent magnet from powdered MnBi, 1035
Huber, H., with P. Guénard, interaction of space-charge waves in crossed magnetic and electric fields, 1526
—— with others, amplification by space-charge waves, 278, oscillations in whole-anode magnetron related to, 904
Hubl, F., frequency-meter for very low frequencies, 3375
Hübner, R., thyratron as switching and control valve, 902
Hübner, W., bridge circuit for feeding several loads, 1491
Hudson, C. S., with A. G. Milnes, 400-c/s and 1·6-kc/s transductors, 3216
Hudson, R. F., with D. R. Scott, analogue computer for mine-ventilation networks, 3349
Hufford, G. A., wave propagation through inhomogeneous medium, 2415
Hugenholtz, E. H., impulse-governed oscillator, a system for frequency stabilization, 2607
Huggins, P., changing the phase of a sinusoidal l.f. voltage, 330; electronics in resistance welding, 502; combined timer and cycle counter, 770
Huggins, W. H., phase principle for complex-frequency analysis, 918
Hughes, R. C., and P. P. Coppola, electrical conductivity of oxide emitters, 894; barriated tungsten emitters, 1189
Hughes, W. L., locked-oscillator frequency dividers, using nonlinear elements, 1281, using thyrite elements, 3560
Hull, J. F., G. Novick and B. D. Kumpfer, high-power delay line for travelling-wave amplifier or oscillator, 2828
Hulls, L. R., and K. A. Mackenzie, electronic h.v. insulation tester, 480
Hum, D. M., with others, electronic band structure of PbS, 2037
Humbel, F., F. Jona and P. Scherrer, anisotropy of dielectric constant of ice, 2027
Humphrey, J. N., F. L. Lummis and W. W. Scanlon, capacitance effects in thin conductive films, 2682
Hung, C. S., with R. M. Baum, activation energy of heat-treatment-induced lattice defects in Ge, 742
Hunsinger, W., electrical measurement equipment at 1952 Technical Fair, Hanover, 166
Hunt, G. A., with A. R. A. Rendall, transmitter combining circuits, 870
Hunt, G. J., and E. W. Elliott, sine-squared pulse, 3377
—— and L. G. Kemp, group-delay-distortion measuring equipment, 1076
—— with others, equipment for impedance matching and measurement at v.h.f., 1747
Hunt, K. L., collective electron ferromagnetism, 1988
Hunter, L. P., and H. Fleisher, graphical analysis of transistor switching circuits, 653

World Radio History

Hupert, J. J., evaluation of f.m. distortion in tuned interstages, **3550**
—— A. Przedpelski and K. Ringer, double-counter discriminator, **684**
Hurlburt, E. H., with R. C. Ellenwood, determination of impedance with double-slug transformer, **774**
Hurrie, K., e.m. horns with phase-correcting lenses, **1242**; excitation and radiation of microwave lenses, **3486**
Husson, R., conditions relating to aesthetics of music, **1882**
Hutchinson, G. W., possible relation of galactic radio noise to cosmic rays, **97**
Hutter, R. G. E., space-charge-wave valves, **1856**
Hylas, A. E., and W. V. Tyminski, u.h.f. grid-dip meter, **2080**
—— with W. V. Tyminski, wide-band hybrid ring for u.h.f., **960**

Ichijo, B., measuring dielectric constant and loss angles of semiconductors, **2380**
Iglitsyn, M. I., electrical properties of multicrystal Se, **2690**
Ignat'eva, L. A., and S. T. Kalashnikov, resistance of metals at high current density, **1377**
Ikeda, K., with others, a.c. magnetization characteristics of a perminvar wire, **2703**
Ikegawa, T., and J. Okada, resistivity of artificial graphite, **1041**
Ikeno, Nobuiti, with others, networks with maximally flat delay, (D)**2259**
Ilowite, R., with G. E. Hamilton, grey-scale generator, **565**
Ince, C. R. S., atomic clocks and frequency stabilization, (D)**1422**
Induni, G., modern h.v. oscillographs with cold cathode, **2743**
Ingard, U., influence of meteorological conditions on sound propagation, **2533**
Ingle, D. P., with others, c.r. tubes with internal pole pieces, **257**
Inn, E. C. Y., with others, formation of D layer, **2652**
Inuishi, Y., temperature dependence of contact noise, **2952**
Ireland, J. R., magnetostriction in alnico-5, **2344**
Isakovich, M. A., scattering of waves by irregular surface, **2969**
Isbell, D. E., with others, microwave measurements on metal powders suspended in wax, **2326**
Isberg, P., with N. Forsberg, 1-MV van de Graaff generator for ion accelerator, **184**
Isbister, E. J., and W. R. Griswold, harbour radar installations at Boston, Long Beach, New York and Liverpool, **1685**
Ishikawa, K., with T. Hibi, spectral dependence of thermionic emission from (Ba-Sr)O cathodes, **284**
Iskraut, R. W., angular momentum in Dirac's new electrodynamics, **1297**
Israel, H., height of atmospheric electric-equilibrium layer, **1343**
—— and H. W. Kasemir, studies of atmospheric potential gradient, **1355**
Isted, G. A., multiple bursts of signal in long-distance v.h.f. propagation, **2419**
Ito, R., end effects in G-M counters, **2411**
van Itterbeek, A., with others, influence of magnetic field on resistance of Fe films, **1039**
Ives, R. L., recorder keep-alive circuit, **473**
Ivey, H. F., effect of V_f on I_a of diode, **1194**; space-charge-limited currents between inclined plane electrodes, **2509**
Iwata, T., with others, a.c. magnetization characteristics of a perminvar wire, **2703**

Jacka, F., southern auroral zone defined by homogeneous arcs, **3310**
Jackson, C. H., with others, evaporated-point-contact rectifiers, **2179**
Jackson, K., and R. O. Jenkins, use of Ni in valves, **2357**, **3629**
Jackson, W., with M. M. Z. Kharadly, properties of artificial dielectrics including arrays of conducting elements, **2902**
Jacob, L., with W. W. H. Clarke, characteristics of l.v. electron immersion objective, **2410**
Jacob, P. B., Jr, and G. M. L. Sommerman, dependence of breakdown direct voltage on humidity and time, **2290**
Jacobs, H., J. Freely and F. A. Brand, mechanism of field-dependent secondary emission, **998**
Jacot, H., digest of Wiener's theory of stationary time series, **328**
Jaffe, H., with W. R. Cook, Jr, ferroelectricity in oxides with fluorite crystal structure, **1374**, **2324**
de Jager, F., delta modulation, **3712**
—— with others, delta modulation, **543**
Jager, J., with H. H. van Abbe, application of Type-DK92 heptode at 30 Mc/s, **813**
Jain, S. C., and K. S. Krishnan, thermionic constants of metals of the first transition group, **1392**, **2700**
Jakes, W. C., Jr, wide-band matching with directional coupler, **29**; analysis for microwave aerial with plane reflector, **1243**
James, I. J. P., fluctuation noise in television-camera amplifier, **1837**
Jan, J. P., temperature variation of Hall effect in Fe and Ni, **1706**
Jancel, R., and T. Kahan, effects of crossed magnetic and alternating electric fields in ionosphere, **1995**; propagation of plane e.m. waves in ionosphere, **2766**
—— with T. Kahan, conductivity and dielectric tensors for ionized medium, **2291**
Janes, R. B., with others, performance of vidicon camera tube, **249**
Janisz, T., a.f. filters using negative feedback, **3545**
Jansen, C. G. J., and R. Loosjes, velocity distribution of electrons of pulsed thermionic emitters. **2837**; graphs for calculation of work function of thermionic emission, **3583**
Jasberg, J., high-power klystron amplifier, **3161**
Jassin, H., attenuation measurements on coaxial cables in range 1 Mc/s–4 kMc/s, **2072**
Jaynes, E. T., impedance in periodically loaded waveguides, **626**
Jeffress, L. A., H. C. Blodgett and B. H. Deatherage, masking of tones by noise as function of interaural phase, **9**

Jehn, K. H., and R. C. Staley, correlations of 100-Mc/s propagation with meteorological effects, **2772**
Jekelius, K., permanent-magnet focusing for c.r. tubes, **573**
Jenkins, H. G., A. H. McKeag and E. E. Welch, phosphors for television c.r. tubes, **1869**
Jenkins, J. A., and R. A. Chippendale, high-speed photography by means of image converter, **2751**
Jenkins, J. B., automatic measurement of ionospheric absorption of oblique-incidence signals, **2313**
—— and G. Ratcliff, automatic measurement of ionospheric absorption of vertical-incidence pulse signals, **1680**, (D)**3305**
Jenkins, R. O., with K. Jackson, use of Ni in valves, **2357**, **3629**
Jennings, R. E., with others, phase stability of electron cyclotron (microtron), **2090**
Jennings, W. W., and P. Vanet, direct-vision stereo-projection screen, **375**
Jenny, F., with others, Swiss developments in h.f. technology, **1548**
Jensen, R. E., and B. W. Currie, orientations of auroral displays in Canada, **3307**
Jepsen, R. L., and T. Moreno, f.m. distortion in reflex klystrons, **1545**
Jerome, C. W., with others, electroluminescence, **2956**
Jerrard, R. P., with H. Poritsky, integrable case of electron motion in electric and magnetic field, **76**
Jesty, L. C., colour television, (D)**1493**; television as a communication problem, **1820**
Jeudon, A., electronic balance, **3685**
Jinkings, P. W., 400-W h.f. 4-channel transmitter Type HC.100, **3135**
Joffe, A. F., with A. V. Joffe, relaxation processes in rectifying pairs of semiconductors, **3620**
Joffe, A. V., and A. F. Joffe, relaxation processes in rectifying pairs of semiconductors, **3620**
Johannin, P., with J. P. Pérez, piezoelectric resonance of quartz up to 5000 atm, **442**
John, H., with W. Grattidge, electronic properties of BaS, **893**
—— with others, double activators in oxide-cathode base alloys, **3152**
Johnson, E. G., and A. O. Nier, aberrations in sector-shaped e.m. lenses, **3680**
Johnson, G. F., television a.g.c. circuit, **250**
Johnson, G. H., effect of impurities on conductivity of TiO_2, **2683**
Johnson, H., with L. J. Giacoletto, u.h.f. triode design, **1536**
Johnson, H. R., and J. R. Whinnery, travelling-wave-valve oscillators, 1872, (C)**3750**, with electronic tuning, **3454**
Johnson, L. J., high-speed magnetic amplifier, **3512**
Johnson, M. H., electric and diffusion currents in E-layer displacements, **385**
Johnson, R. A., with others, measurement of small-signal parameters of transistors, **3358**
Johnson, S. L., television studio lighting equipment, **864**
Johnson, V. A., and F. M. Shipley, adiabatic Hall effect in semiconductors, **3018**
—— and W. J. Whitesell, theory of magnetoresistive effect in semiconductors, **2329**
—— with others, low-temperature Hall curve for *n*-type Ge, **426**
Johnson, W. F., commercial radar equipment, **730**
Johnston, D. L., with G. W. A. Dummer, printed and potted electronic circuits, **2926**
Johnstone, C. W., new design of pulse-height analyser, **1920**
—— J. F. Kalbach and H. J. Lang, telemetry system for large e.s. accelerator, **794**
Jolivet, P., new e.s. influence machine, **2459**; new electrical insulating materials, **3634**
Jolly, A. C., with C. V. Drysdale, Electrical Measuring Instruments: Part 1, (B)**2398**
Jona, F., with others, anisotropy of dielectric constant of ice, **2027**
Jones, A. F., suppression of radio interference from telephone apparatus, **1476**
Jones, C. H., effects of noise on N.T.S.C. colour standards, **2467**
Jones, D. S., diffraction, simplifying technique for problems in, **374**, inconsistency in theory of, **696**, by an edge and by a corner, **711**, by thick semi-infinite perfectly conducting plate, **2295**
Jones, E., S. Edelman and A. London, long-tube method for determination of sound absorption, **13**
—— with others, television valves and a.c./d.c. receivers, **1503**
Jones, E. M. T., and R. A. Folsom, Jr, circular dielectric-disk aerial, **2572**
Jones, F. L., British Association discussion on electrical discharges in gases, **701**; initiation of discharges at electrical contacts, **3579**
—— and C. G. Morgan, surface films and field emission of electrons, **3267**
—— and E. T. de la Perrelle, field emission of electrons in discharges, **1962**
—— and G. C. Williams, low-pressure breakdown of gases in nonuniform fields, **2830**
—— with others, time lags in electrical breakdown of gases, **3262**
Jones, G. E., Jr, harmonic-distortion meter, **1078**
Jones, H. Spencer, and P. J. Melotte, harmonic analysis of geomagnetic field for epoch 1942, **3279**
Jones, R. E., measurement of phase change of ionosphere pulse echoes, **3599**
—— G. H. Millman and R. J. Nertney, heights of ionospheric winds determined from long-wave measurements, **2311**
Jones, R. F., Montreal conference on application of radar in meteorology, **1361**
Jones, R. V., with W. Paul, absorption spectra of PbS at various temperatures, **2020**
Jong, A. S. G., with G. E. Burridge, transmission factors for power-line carrier network, **3704**
Jonker, G. H., and J. H. van Santen, ferromagnetic compounds of Co with perovskite structure, **2701**
Jonker, J. L. H., angular distribution of secondary electrons from Ni, **584**; short-length picture tube, **3737**
—— with others, decade tube for high counting rates, **3762**

World Radio History

Jordan, E. C., with others, meteorological effects on v.h.f. propagation, **1784**
Jouguet, M., effects of amplitude and phase distortion on limited-spectrum television signals, **1177**
Jung, P., viscometer with servomechanism, **3673**
Junger, M. C., formula for acoustic field of vibrating cylinder, **1554**
Justi, E., and G. Lautz, impurity and intrinsic semiconduction of intermetallic compounds, **3619**

Kachickas, G. A., and L. H. Fisher, time lags of field breakdown in N_2, **1308**
Kaden, H., dielectric and metal waveguides, **28**; pulse response of cables with nonuniform characteristic impedance, **2070**; characteristics of coaxial cables with helical-strip insulation at frequencies > 1 kMc/s, **3184**
Käding, H., hinged mast for mobile television transmitter, **1160**
Kafka, H., design of voltage transformers, **1599**
Kahal, R., synthesis of quadripole networks, **1263, 3538**
Kahan, T., and R. Jancel, conductivity and dielectric tensors for ionized medium, **2291**
—— with R. Jancel, effects of crossed magnetic and alternating electric fields in ionosphere, **1995**; propagation of plane e.m. waves in ionosphere, **2766**
Kahn, F. D., possible radiation mechanisms of radio stars, **1328**
Kahn, L., high-temperature operation of metallized-paper capacitors, **345**
Kaisel, S. F., with others, developments in travelling-wave valves, **1524**
Kaiser, T. R., and J. S. Greenhow, decay of radio echoes from meteor trails, **1978**
—— with others, radio reflections from meteor trails, **1979**
Kaiser, W., audiometer at Technische Hochschule, Stuttgart, **1891**
—— with E. Zwicker, modulation threshold in audible range, **1892**
Kalashnikov, S. G., and Ya. E. Pokrovski, influence of surface on type of conduction of semiconductor, **2686**
—— with L. A. Ignat'eva, resistance of metals at high current density, **1377**
Kalbach, J. F., with others, telemetry system for large e.s. accelerator, **794**
Kales, M. L., transmission modes in waveguides containing ferrites, **1586, 2888**
Kalinin, V. I., and T. P. Ryazonova, theory of multisegment magnetron, **3458**
Kallenbach, W., tone-pitch recorder for phonetics research, **1226**
Kallmann, H., B. Kramer and A. Perlmutter, induced conductivity of luminescent powders, **2021**
Kallmann, H. E., remodulation in cascade-type electron multipliers, **1519**
Kallmann, H. K., continuous layer formation in atmosphere under influence of solar radiation, **2651**; physical properties of atmosphere between 80 and 250 km height, **3286**
Kalmus, H. P., J. C. Cacheris and H. A. Dropkin, nonquantized f.m. altimeter, **3311**
Kaltbeitzer, K. H., with R. Gressmann, determination of service area for planning u.s.w. networks, **213**
Kambe, K., hysteresis loops of $BaTiO_3$ ceramic at h.f., **3013**
——I. Nakada and H. Takahasi, hysteresis loops of $BaTiO_3$ ceramic at h.f., **3012**
Kamiyama, H., statistical study of minimum frequency in E-region *h'f* curve, **2654**
Kan, M., with others, frequency-sweep $h'F_2$ measurements, **3297**
Kanai, Y., transistor action of Si crystals, **2823**
Kanaya, S., with others, attenuation characteristics for h.f. and m.f. waves, and application to field-strength calculations, **2774**
Kandiah, K., and D. E. Brown, high-gain d.c. amplifiers, **172**
Kandoian, A. G., R. A. Felsenheld and W. Sichak, high-gain loop aerial for television broadcasting, **1236**
Kane, D. F., with others, lattice constants and dielectric properties of $BaTiO_3$-$BaSnO_3$-$SrTiO_3$ ceramics, **1718**
Kangro, G., with R. Suhrmann, semiconductor properties of systems K-Sb, Cs-Sb, K-In, Cs-In, **2030**
Känzig, W., with others, properties of very small ferroelectric particles, **3007**
Kapp, R. O., calculation of transmission-line constants, **619**
Karbowiak, A. E., with H. M. Barlow, cylindrical surface-wave resonator for determination of velocity of short e.m. waves, **3355**
Karo, D., shunted-T circuit for impedance measurements from a.f. to v.h.f., **1062**
Karolus, A., colour television, **239**; tuning-fork type of quartz oscillator for 1–20 kc/s, **2267**
Kasemir, H. W., studies of atmospheric potential gradient, **1354**
—— with H. Israël, studies of atmospheric potential gradient, **1355**
Kaspin, B. L., and others, magnetic striping techniques, **2206**
Kassander, A. R., Jr, with R. M. Stewart, Jr, electronic statistical tabulator, **2369**
Kassel, K., effect of lattice defects on optical absorption of Cu_2O, **1384**
—— with G. Blankenburg, semiconductor properties of Cu_2O in relation to production methods, **1383**
Kästner, S., with K. Altenburg, demodulation of ultrasonic waves in liquids, **2864**
Kates, J., improving read-around ratio in c.r. storage tubes, **3353**
—— and V. G. Smith, Scotch-plaid raster for c.r. tube digit storage, **3649**
Kato, Y., new theory of magnetic storms, **2646**
—— and J. Ossaka, variation of geomagnetic field during bay disturbances, **2972**
Katsman, Yu. A., oscillations of uniform electron beams, **3144**
Katz, H., metal capillary cathodes, **3148**
Katzenstein, H. S., with S. S. Friedland, factors influencing life of self-quenching counters, **2104**
Kaufman, H., with R. L. Sternberg, theory of multiple nonuniform transmission lines, **1581**
Kaufman, S., analogue computer for geophysical data, **2718**
—— with H. H. Wieder, plastic electrets, **2025, 3323**
Kaufmann, A., applications of tensor theory to linear electronic circuits, **659**
Kauke, J., negative resistance in Ge diodes, **2180**
Kawamura, S., with K. Noga, photoelectric emission from BaO, **2322**
Kazanowski, H. F., with W. P. Bennett, 1-kW tetrode for u.h.f. transmitters, **1206**
Kazarnovski, D. M., variation with time of the dielectric properties of ferroelectric ceramics, **2026**
Kear, F. G., with others, multiple television and f.m. aerial system, **1589**
Keck, P. H., and J. Broder, solubility of Si and Ge in Ga and In, **3033**
Keen, A. W., scanning-current linearization by negative feedback, (A)**248**; anode-follower derivatives, **658**; precision synchronizing system for large-screen television equipment, **1812**; reduction of pulse interference in television receivers, **1843**; triode transformation groups, **3529**
Keidel, L., methods and apparatus for room-acoustics measurements, **606**; multiple-Rayleigh-disk mesh arrangement, **1228**
Keil, A., and G. Offner, production and testing of precious-metal coatings on insulating materials, **2052**
Kelbg, G., with H. Falkenhagen, optical method for determining permittivity and permeability, **995**
Kelen, A., micromanipulator for location of point contacts on semiconductors, **2999**
Kell, R. D., and A. C. Schroeder, optimum utilization of r.f. channel for colour television, **3431**
Keller, J. B., diffraction of pulse by 90° wedge, **986**
Keller, K., with others, thermally produced lattice defects in Ge, **1697**
Kelly, J. M., J. O. Stenoien and D. E. Isbell, microwave measurements on metal powders suspended in wax, **2326**
Kelly, S., piezoelectric-crystal pickups, **1904**
Kel'man, V. M., and I. V. Rodnikova, motion of charged particles in e.m. field of linear current and e.s. field of cylindrical capacitor, **75**
Kelso, J. M., determination of vertical distribution of electron density in ionosphere, **409**
—— and others, polarization of vertically incident long radio waves, **806**
Kemény, A., with Á. Bardócz, electronic spark timing device, **455**
Kemp, E. L., gated decade counter, **1256**
Kemp, L. G., with G. J. Hunt, group-delay-distortion measuring equipment, **1076**
Kemp, W. D., television recording, **847, 2468**
Kempthorne, O., The Design and Analysis of Experiments, (B)**1419**
Kende, G., borocarbon resistor characteristics, **340**
Kent, E. L., and C. J. Temmes, electronic musical instrument, **317**
Keonjian, E., and J. S. Schaffner, experimental investigation of transistor noise, **887**; noise in transistor amplifiers, **1288, 2279**
Kerker, M., with others, scattering and attenuation by nonspherical atmospheric particles, **2314**
Kerkhof, F., and W. Werner, Television, (B)**578**
Kerr, F. G., harmonic distortion and negative feedback, (D)**3253**
Kersta, L. G., solid sound, **11**
Kessler, G., direct-voltage valve amplifier, **981**
Kessler, W. J., and S. P. Hersperger, recent developments in radio location of thunderstorms, **1020**
Ketchledge, R. W., and T. R. Finch, equalization and regulation in L3 coaxial-cable system, **3410**
Kettel, E., stability of quartz-controlled oscillators, **1274**; quartz-crystal circuit with variable coupling as f.m. oscillator and discriminator, **1277**
Khalek, A., annual variation of reduced density and mean temperature of atmospheric ozone in Afghanistan, **2979**
Kharadly, M. M. Z., and W. Jackson, properties of artificial dielectrics including arrays of conducting elements, **2902**
Khodakov, A. L., with I. N. Belyaev, dielectric properties of $PbTiO_3$ single crystals, **1410**
—— with others, dielectric properties of $BaTiO_3$ single crystals, **3009**; composition and properties of $BaTiO_3$ ceramics in strong fields, **3010**
Khokhlov, M. Z., with others, single-electrode discharge at 31·7 Mc/s, **1307**
Kiely, D. G., waveguide rotary switch, **2241**; experiments with single-wire transmission lines at 3-cm wavelength, **3186**
v. Kienlin, U., with others, aerial systems for 24-channel p.p.m. beam R/T system, **822**
Kietz, H., stereoaudition, **2546**
Kihlberg, G., with others, integrating amplifier for c.r.o. recording of magnetic flux, **3062**
Kijakowski, G. W., slow-acting deflection-synchronization circuits, **3736**
Kikuchi, M., and T. Onishi, investigations of electrical forming of Ge rectifiers, **2032**
Kilvington, T., cable links for television outside broadcasts, **1145**
Kinchin, G. H., electrical properties of graphite, **2051**
Kinder, E., design of small electron microscopes, **2756**
King, D. D., with S. H. Dike, gain and back-scattering cross-section of cylindrical aerial, (D)**2894**
King, G., and others, microwave techniques for communication links, **219**
King, L. H., reduction of forced dynamic error in closed-loop systems, **3423**
King, R. W. P., dipole with tuned parasitic radiator, (D)**324**; aerials, electrically short, theory of, **628**, cylindrical, (D)**629**; alternative method of solving Hallén's equation, **1908**
King, W. C., and W. Gordy, spectroscopy at 1–2-mm λ, **2623**
Kingdon, B. E., circular waveguide magic-T and its applications, **3219**
Kintner, P. M., flux-charge concept in magnetic-amplifier analysis, **337**
Kip, A. F., with others, electron-spin resonance in Si semiconductor, **3342**

World Radio History

Kirby, M. J., and R. M. Giulianelli, stability of varying-element servo-mechanisms, **3723**
—— with others, servomechanism transient performance from db/log-*f* plots, **3721**
Kirschbaum, H. S., analysis of parallel-connected magnetic amplifiers, **(D)944**
Kirschner, F., with T. Korn, analysis of transient acoustic phenomena by means of reduced-scale models, **921**
Kirschner, U., general rules for Laplace transformation, **764**; modulation problems, **2439**; realization of a.c. resistance, **3493**
Kirschstein, F., frequency allocation at 1952 European Broadcasting Conference, Stockholm, **1799**
—— and H. Bödeker, modulation distortion in television reception, **260**
Kiryluk, W., voltage-regulator tubes, **1871**
Kitagaki, T., focusing method for large accelerators, **2406**
Kitai, R., impulsive e.m. fields, **38**; pulse response of a.m. receiver, **1115**
Kitchen, F. A., and K. W. Tremellen, ionospheric influences in television reception, **1176**
—— B. G. Pressey and K. W. Tremellen, ionospheric propagation of v.l.f., l.f. and m.f. waves, **1781**
Kittel, C., with others, electron-spin resonance in Si semiconductor, **3342**
Kiyasu-Zen'iti, Nobuiti Ikeno and Sigeharu Yamada, networks with maximally flat delay, **(D)2259**
Klasens, H. A., fluorescence centres and traps in ZnS, **2024**
—— with A. Bril, intrinsic efficiencies of phosphors under c.r. excitation, **3607**; new phosphors for flying-spot c.r. tubes, **3608**
Klätte, G., cut-off attenuators for waveguide circuits, **1938**
Klein, C. A., production of radio waves by means of the Tcherenkov effect, **1970**
Klein, W., problems of radio transmission for mobile telephony systems, **1486, 3417**; measurement of cm-wave attenuation factor of quadripoles, **2071**; equivalent circuits using negative two-pole elements, **2247**; equivalent-circuit diagrams for transistors, **3522**
—— and W. Friz, characteristics of travelling-wave valve with dispersive delay line, **2826**
Kleinknecht, H., Si single-crystal rods, **422**
Kleinwächter, H., calculation of electron paths by means of complex vector loci, **77**; excitation of e.m. fields by current waves, **279**; travelling-wave valve with corrugated rectangular waveguide, **1186**
—— and H. Weiss, consequences of amplitude spectrum in pulse technology, **3105**
Klemperer, O., electron optics symposium, **3681**
de Klerk, J., automatic c.r.o. trace brightening, **3369**
Klick, C. C., luminescence and photoconductivity of CdS at edge of absorption band, **1691**
Klie, R. H., with others, L3 coaxial-cable carrier system, **3409**
Kline, H. W., industrial frequency standard, **456**
Klipsch, P. W., historical development of corner type of loudspeaker unit, **3178**
Kloot, N. H., with E. J. Williams, interpolation in series of correlated observations, **2362**
Klopfenstein, R. W., impedance matching with transformer sections, **2249**
von Klüber, H., corona observations at solar eclipse, 25th Feb. 1952, **716**
Kluck, J. H., and R. E. Larson, S-band frequency-sweep generator and test set, **3671**
Kluge, W., control of self-maintained discharge currents by illumination of cathode, **3264**
—— and S. Weber, pulse irradiation of composite photocathodes, **3448**
van der Knaap, P. D., with others, ECL80 and EQ80 valves in flywheel synchronizing circuits, **2168**
Knechtli, R., with H. J. von Baeyer, analysis of multiconductor systems with h.f. TEM waves, **26**
Knight, C. R., and K. C. Harding, specifications for reliable valves, **270**
Knight, G., Jr, R. A. Johnson and R. B. Holt, measurement of small-signal parameters of transistors, **3358**
Knight, L., coil winding data, **647**
Knol, K. S., and G. Diemer, h.f. diode admittance with retarding field, **290**
—— with G. Diemer, noise of electronic valves at v.h.f., **3758**
Knoop, E., gas-filled triodes, discharge processes in, **1542**, as pulse amplifier, **2274**
Knudsen, H. L., mutual radiation resistance of aerials and arrays, **32**; calculation of some definite integrals in aerial theory, **1238**; field of ring array of tangential or radial dipoles, **2570**; field in rectangular waveguide with longitudinal conducting membrane, **2882**
—— and M. Andreasen, theory of plane reflectors in aerial systems, **1913**
Kobayashi, A., with others, composition of Cs-Sb photocathodes, **2824**
Kobayashi, T., with others, field strength, of scattered waves in r.f. propagation, **2775**, h.f. sky wave, graphical calculation of, **2777**; frequency of occurrence of fE_s and $fmin F$, **2985**
Kober, H., absorption in an electron-gas mixture, **2297**
Kobierski, H., investigations on R/T for trains, **225**
Koch, B., frequency stabilization in microwave range, **46**; radar measurement of velocity of projectiles, **174**; reflection of microwaves by explosion-wave fronts, **2086**
Koch, E., Weser-Ems power-supply carrier-current network, **2435**
Koch, K. M., with L. Halpern, Corbino effect and magnetic variation of resistance in Bi, **1710**
—— with A. Nedoluha, mechanism of resistance variation in magnetic field, **377**
Kock, W. E., acoustic gyrator, **1874, 2532**
Koenig, J. F., design of damper-stabilized instrument servomechanisms, **549**
Koenigsberg, E., conductivity of thin films in longitudinal magnetic field, **3626**
Kohman, G. T., with others, polyethylene terephthalate as capacitor dielectric, **440**
Koike, Y., and S. Yamanaka, limiting frequency of triode oscillator, **1201**; amplification constants of triodes, **1537**
Kolb, E. D., with W. P. Slichter, Ge crystals, impurity effects in thermal conversion of, **116**, solute distribution in, **3343**
Kolb, O., with R. Feldtkeller, complex permeability of high-μ ferrite core, **1705**
Kollath, R., and D. Menzel, measurement of charge on moving electrons, **2958**
—— with R. Fleischmann, method for measuring charge of fast electrons, **2957**
Koller, L. R., monolayer fluorescent screens, **3761**
Kolodziejczyk, L., influence of magnetic impulses on kinetic energy of electrons, **2300**
Kompfner, R., travelling-wave valves, **2183**
Konig, H. W., low-noise electron streams, **1183**
Kono, T., experiments on scattered echoes, **2776**
Konstantinova-Shlezinger, M. A., N. A. Gorbacheva and E. I. Panasyuk, thermoluminescence of sulphate-base materials, **3006**
Konstantinowsky, K., recent information on electrical breakdown, **3632**
Koppe, H., solar activity and the atmosphere, **1323**
Köppen, H., thermal grid emission and its elimination, **899**
Korchak, A. A., and Ya. P. Terletski, e.m. radiation from cosmic protons and r.f. radiation from galaxy, **1331**
Korman, N. I., E. B. Herman and J. R. Ford, analysis of microwave-aeral side-lobes, **41**, **(C)2226**
Korn, T., and F. Kirschner, analysis of transient acoustic phenomena by means of reduced-scale models, **921**
Kornblith, L., Jr, with others, synchrocyclotron for 450-MeV protons, **1764**
Kornetzki, M., relation between hysteresis coefficient and permeability, **756**; alternating-field losses in magnetic cores with air gaps, **1721**; nonlinearity of titanate capacitors, **2916**
—— and others, measurements on high-μ ferrite cores, **1032**
Koros, L. L., measurements on a.m. injection-locked magnetron transmitter, **1060, 2483**
Koschel, H., with K. Braun, reference-level test equipment for telephone circuits, **777**
Kosmahl, H., with R. Gebauer, construction, properties, operation and applications of klystrons, **596**
Kösters, A., acoustic particle-velocity measurements in liquids with Rayleigh disk, **305**
Kostriza, J. A., microstrip components, **623, 2214**; composite-dielectric coaxial line, **3185**
Kotani, S., with T. Arizumi, gettering process of Ba, **2321**
Koteswaram, P., physical properties of upper atmosphere over India, **403**
Kotosonov, N. V., measurements of dielectric constant at cm λ, **2069**
Kouskoff, G., vector representation of sinusoidally varying quantities, **1919**
Kovacs, A., and P. Laurent, effect of fatigue on magnetic properties of Ni-Cr steels, **1037**
Kraft, L. G., with L. Weinberg, measurements of detector output spectra, **3699**
Kramer, B., with others, induced conductivity of luminescent powders, **2021**
Kramer, J., surface investigations on metals and nonmetals with exo- and photo-electrons, **2301**
Krapf, S., magnetization characteristic of ferromagnetic materials, **1704**
Krastel, R., multimesh *RC* networks for phase-shift oscillators, **1627**; phase and group delay, **2258**
Kraus, J. D., and E. Ksiazek, beam aerial-array for radio astronomy at Ohio State University, **3490**
Krauss, H. L., with others, 3-terminal *RC* networks, cascaded, synthesis of, **656**, paralleled, synthesis of, **3536**
Krautz, E., spectroscopic investigation of oxide cathodes in gas discharges, **1188**
Kretsch, H. W., with J. F. Engelberger, electromechanical transducer for telemetry, **2412**
Kretzmann, R., photoelectric register-control devices, **1096**
Krishnan, K. S., with S. C. Jain, thermionic constants of metals of the first transition group, **1392, 2700**
Krisilas, J. G., with others, liquid-dielectric r.f. coaxial cables, **3472**
Kroebel, W., direct-voltage amplifier, with high input resistance, **787**, for voltages down to 10^{-9} V, **2276**; location of cable faults by pulse-echo methods, **2727**
Kröger, F. A., A. Bril and J. A. M. Dikhoff, single-component white screen for television tubes, **111**
Krömer, H., theory of Ge rectifier and transistor, **2821**
Kronjäger, W., and H. Wallor, Rhine R/T service, **542**
Krumbiegel, J., photoelectric measurements on ZnS single crystals, **732**
Krusen, F. H., with J. F. Herrick, physiological effects of microwaves, **2748**
Krzikalla, W., echo-sounding equipment with new indicating instrument, **1092**
Ksiazek, E., with J. D. Kraus, beam aerial-array for radio astronomy at Ohio State University, **3490**
Kudo, H., with others, *h'f* ionosphere measurements at Wakkanai, Japan, during eclipse of 9th May 1948, **2659**
Kuh, E. S., potential-analogue network synthesis, **3530**
Kuhl, W., directivity of microphones on surface of sphere, **613**; properties of water-filled tubes for acoustic impedance and velocity measurements, **2866**
Kühn, L., theory of magnetic amplifiers, **2909**
Kühne, R., magnetic-field measurement with iron-cored magnetometer by harmonic method, **165**
Kukel, J., and E. M. Williams, helical-winding structures in exponential-line pulse transformers, **2234**
Kulcsar, F., with D. A. Berlincourt, electromechanical properties of $BaTiO_3$ compositions, **1042**
Kulp, M., interference caused by interfering transmitters, **531**; effective value of interfering modulated oscillations, **1475**

World Radio History

Kumpfer, B. D., with others, high-power delay line for travelling-wave amplifier or oscillator, **2828**
Kuntzmann, J., J. Daniel and Min-Yuan Ma, stability of control systems, **1489**
Kunze, P., and G. Schulz, l.v. counter tubes, **3085**
Küpfmüller, K., regulating systems with time delay, **2087**
Kuritsyna, E. F., magnetic viscosity of Ni-Zn ferrites, **3621**
Kurshan, J., extension of operating-voltage range of valve heaters, **287**
—— R. D. Lohman and G. B. Herzog, c.r. tube plots transistor curves, **1437**
—— with others, use of flying-spot scanner to study photosensitive surfaces, **890**
Kursunoglu, B., gravitation and electrodynamics, **1291**
Kurtze, G., linings for acoustically damped rooms, **1567**
—— and K. Tamm, measurements of sound absorption in water and aqueous solutions of electrolytes, **2196**
Kussl, V., Ohm's law for build-up phenomena, **638**
Kusters, N. L., with D. M. Murray, electromechanical a.c. line-voltage stabilizer, **3726**
Kuwabara, G., fatigue of Ag-Cs photocells, **3137**

Laaff, O., parabolic aerials with extremely good matching, **326**; approximate determination of transmitter range, **2414**
Labhart, H., antiferromagnetism, **3585**
Labin, É., channel width for colour-television transmission, **2805**
Labrie, L. J., with D. F. Ciccolella, h.f. crystal units for filter networks, **3552**
Labrum, N. R., scattering of radio waves by particles, **1362**, at cm λ, **1363**
Labus, J., space-charge waves, influence of Lorentz force on, **2182**, in electron streams, **2486**
Lacam, A., and J. Noury, velocity of ultrasonic waves in Ar at pressures up to 950 atm, **1559**
Lacour, H. R., with others, plastic deformability of Ge, **2033**
Lacy, R. E., and C. E. Sharp, f.m. microwave radio relay equipment, **1127**
Laett, H., the Dôle as site for television transmitter, **246**; design of compensated wide-band amplifiers, **1949**
—— and J. Dufour, the Dôle as site for television transmitter, **2166**
Lafferty, R., abac for correction of Q-meter errors due to valve-voltmeter loading, **783**
Lagasse, J., with M. Teissié-Solier, generators of repeated surge waves, **1088**
Lagrenaudie, J., properties of boron, **1696**, **2031**
—— with others, conductance of semiconductor in electric field, **1695**; preparation and properties of arsenide semiconductors, **3325**
Lahure, L., and J. Fontaine, radio equipment and navigation aids aboard ship, **3418**
Lallemand, A., electron-multiplier photocells, **1853**
Lally, P. M., spacc-harmonic travelling-wave valve, **2831**
Lalmi, —, with — Quiquandon, central telecommunications office for civil aviation, **3419**
Lamb, J., ultrasonics in liquids, **1563**
Lambert, D. E., coaxial-line v.m. oscillator for f.m. radio links, **1211**
Lamoral, R., absorption coefficient of acoustic materials, **3465**
Lampert, M. A., and A. D. White, microwave technique for studying gas discharges, **3263**
—— with L. Goldstein, new linear passive nonreciprocal microwave circuit component, **1265**, **3232**
—— with others, microwave determination of electron density and collision frequency in gas discharge, **380**
Lanczos, C., solution of systems of linear equations, **145**
Lander, G., analogies between electrical and mechanical devices, **988**
Landesman, S., distortion in class-A push-pull amplifiers, **2610**
Landmark, B., polarization of magneto-ionic z-component, **1775**
—— with L. Harang, 35- and 74-Mc/s pulse echoes observed during aurorae and geomagnetic storms, **2976**
Landsberg, P. T., note on theory of semiconductors, **78**
Landseer-Jones, B. C., theory of aurora, **1358**
Lane, A. L., design techniques for high-frequency transducer with wide-angle beam, **3167**
Lane, J. A., and J. A. Saxton, dielectric dispersion in electrolytes at u.h.f., **698**
—— with A. C. Grace, direct-reading standing-wave indicator, **3066**
Lane, P. E., with W. A. Prowse, u.h.f. breakdown of gas in crossed electric fields, **3261**
Lane, R. N., with others, reverberation chamber with polycylindrical walls, **922**
Lang, H. C., with J. J. Baruch, analogue computer for use in loudspeaker design, **3050**
Lang, H. J., with others, telemetry system for large e.s. accelerator, **794**
Lange, H., selective frequency-spectrum analyser, **2073**
de Lange Dzn, H., investigation of flicker, **1841**; decrease of l.f. signal/noise ratio when increasing i.f. bandwidth, **3404**
Lange, T., investigation of cavitation by ultrasonics, **1560**; measurement of sound attenuation by ceilings, **2871**
Lange, W., variable inductance and application to frequency-sweep oscillators, **683**
Lange-Hesse, G., 27-day variations of D-layer r.f. absorption over Singapore and Slough, **2660**
Langenberger, A., 16th plenary assembly of C.C.I.F., Florence, Oct. 1951, **533**
Langton, N. H., and N. Davy, field above and below infinite corrugated sheet, **2965**
—— with N. Davy, external magnetic field of single thick plate, **2293**
Larach, S., and J. Turkevich, interaction of Mn activator ions in Zn_2SiO_4-Mn phosphors, **2323**
Larguier, R., electronic speed regulators, **1451**
Lark-Horovitz, K., with W. M. Becker, semiconducting Ge films, **3615**
Larson, R. E., with J. H. Kluck, S-band frequency-sweep generator and test set, **3671**
Lasof, S., with others, use of flying-spot scanner to study photosensitive surfaces, **890**
Latham, D., B. D. Power and N. T. M. Dennis, working fluids for diffusion pumps, **1686**
Latimer, K. E., and H. B. MacDonald, possible applications of ferrites, **1396**
Latour, M., magnetic amplifiers, (D)**943**
Latzel, G., with W. Holle, reciprocity calibration of capacitor microphones, **2544**
Lauber, A., acoustic resonators as sound absorbers, **310**
—— with W. Furrer, reverberation-time measurements with warble tones and with white noise, **1571**; 'diffusion' in room acoustics, **1893**
Laudet, M., calculation of potential due to uniformly charged disk, **1651**; field of cylindrical e.s. lens with three slits, **2094**
—— and P. Pilod, potential distribution in e.s. electron lens, **3383**
Lauer, H., operating modes of servomechanism with nonlinear friction, **3421**
Laurent, P., with A. Kovacs, effect of fatigue on magnetic properties of Ni-Cr steels, **1037**
Laurent, T., design of filters by Wagner's methods, **1931**
Lauter, E. A., and G. Bartels, optical refraction and u.s.w. propagation in Baltic area, **521**
Lautz, G., with E. Justi, impurity and intrinsic semiconduction of intermetallic compounds, **3619**
Lavaitte, A., with J. Pottier, current and voltage regulators, **3725**
Lavender, R. W., instruments for testing camera shutters, **2750**
Laver, F. J. M., F. M. Billinghurst and F. J. Lee, automatic-scanning receiver for radio monitoring, **2122**
Law, H. B., 3-gun shadow-mask colour kinescope, **575**
Law, R. R., and others, Ge p-n-p-junction transistor, **876**
Lawrance, R., photovoltaic effect in natural PbS, (C)**2013**; temperature dependence of drift mobility in Ge, **2332**
—— and A. F. Gibson, measurement of drift mobility in semiconductors, **1379**
Lawrence, R. S., maps of 4 ionospheric disturbances, **3296**
Lax, L., and D. Weighton, gamma-control circuit using crystal diodes, **1826**
Leblond, A., O. Doehler and R. Warnecke, new magnetron oscillator with interdigital circuit, **2187**
—— J. Nalot and O. Doehler, natural oscillations and mode changes in multicavity magnetrons, **1543**
Le Bot, J., and S. Le Montagner, measurement of dielectric constant at cm λ, **2067**; s.w.r. meter for the 9·5-kMc/s band, **3368**
—— with S. Le Montagner, measurements of dielectric constants at 9·5 kMc/s, **2068**
Lebow, I. L., with others, phase-bistable transistor circuit, **3515**
Le Couteur, K. J., perturbations in magnetic deflector for synchro-cyclotrons, **2091**
Ledinegg, E., and P. Urban, theory of waveguides, **1582**; theory of forced oscillations in electrodynamic systems, **1622**; first boundary-value problem of Maxwell's equations, **1641**; bandwidth of cm-λ bandpass filters, **1935**; susceptibility of linear antiferromagnetic chain, **2633**
Lee, E. M., radio and television interference problems, **1179**
Lee, E. W., magnetostriction, **1976**
Lee, F. J., with others, automatic-scanning receiver for radio monitoring, **2122**
Lee, G. W., broadcast transmitter remote control system, **2762**
van Leeuwen, C. J., with others, l.f. noise in valves, **1202**
van Leeuwen, F. J., measurement of tension of microphone diaphragms, **2200**
Leevers, N., magnetic recording in cinema-film production, **21**
Léger, P., with P. Prugne, uniform metallization of surfaces by thermal evaporation, **428**
Lehmann, G., rotary amplifiers in servomechanisms, **2451**
Lehmann, H., control characteristics of half-wave self-saturated magnetic amplifiers, **3505**
Lehnert, W. E., factors concerning use of audio transformers, **2577**
Lehovec, K., photoelectric devices utilizing carrier injection, **888**
—— and others, evaporation of Ge films from carbon crucible, **3032**
Leisegang, S., astigmatism of electron lenses, **2097**
Leiss, W. J., with others, moisture aging of powder-core toroids, **2355**
Leithammel, P., with others, integrating amplifier for c.r.o. recording of magnetic flux, **3062**
Le Montagner, S., and J. Le Bot, measurements of dielectric constants at 9·5 kMc/s, **2068**
—— with J. Le Bot, measurement of dielectric constant at cm λ, **2067**; s.w.r. meter for the 9·5-kMc/s band, **3368**
Lempicki, A., conductivity of MgO single crystals, **2327**; origin of secondary electrons, **2336**
Lenihan, J. M. A., velocity of 13·5-kc/s sound waves in air, **605**
Lennartz, H., h.v. generation for c.r.o. and television equipment, **2812**
Lenz, F., and M. Hahn, asymmetry of magnetic electron lenses, **2098**
—— with others, remanence in soft-iron circuits of magnetic electron lenses, **2102**
Leondes, C., and M. Rubinoff, DINA, digital analyser for Laplace, Poisson, diffusion and wave equations, **3045**
Leontovich, M. A., and S. M. Rytov, differential law of electrical fluctuations and influence of skin effect, **2951**
Le Page, L. S., and A. L. P. Milwright, radar and ice, **2673**
Lerner, R. M., effect of noise on frequency stability of linear oscillator, **362**
Leroy, R., reactive T or Π sections resolvable into two matched half-sections, **2590**
Leslie, R. W., and C. Gunn-Russell, remote control and automatic monitoring of Third Programme transmitter, **261**
Lettowsky, F., calculation of h.f. resistance of cylindrical conductors, **3188**
Levell, D. A., hard-valve pulse generator, **364**

World Radio History

Leveque, A., with G. Valladas, background noise in ionization-chamber amplifiers, **1634**
Levi, R., dispenser-type thermionic cathode, **2502**
Levin, M. J., and J. F. Reintjes, 5-channel analogue correlator, **2366, 2720**
Levine, A. K., with S. Levy, preparation of phosphor screens for colour-television tubes, **3440**
Levine, M. A., with W. H. Bostick, demonstration of magne - hydrodynamic waves in ionized He, **89**
Levintov, I. I., approximation to 3/2-power law for finite cathode, **3757**
Levy, I. E., effect of impurity migrations on oxide cathodes, **1858**
—— with F. M. Dukat, cathode-interface effects in television receivers, **2505**
Levy, S., and A. K. Levine, preparation of phosphor screens for colour-television tubes, **3440**
Lewin, L., mutual radiation resistance of aerials and arrays, **(D)627**; theory of waveguide-fed slots, **1915**
—— with others, microwave techniques for communication links, **219**
Lewis, B. G., nonlinear capacitors, **2915**
Lewis, F. D., u.h.f. television monitor, **247**
Lewis, H., with others, design of linear-phase low-pass filters, **1614**
Lewis, N. W., waveform computations by time-series method, **55, (D)1608**
Lewis, R. P. W., reflection of radio waves from layer with vertical and horizontal ionization gradients, **2418**
—— and D. H. McIntosh, diurnal and storm-time geomagnetic and ionospheric variations, **3300**
Lewis, V. S. E., differential amplifier, **(D)1637**
Liandrat, G., with others, conductance of semiconductor in electric field, **1695**
Liberman, A. M., with others, experiments on synthetic speech sounds, **919**
Licklider, J. C. R., process of speech perception, **920**
Lidiard, A. B., spin degeneracy and theory of collective electron ferro-magnetism, **1001**; overlapping energy bands and ferromagnetism, **1662**
Liebmann, G., solution of waveguide and cavity-resonator problems with resistance-network analogue, **(A)150**; pole-piece saturation in magnetic electron lenses, **3386**
Lied, F., physical interpretation of approximation to magneto-ionic equation, **515**
Lien, R. H., radiation from horizontal dipole, **1587**
Liénard, P., with G. Eckart, acoustical characteristic impedances and echoes in stratified media, **4**
Lilienfeld, J. E., and C. Miller, conductivity distribution within dielectric films on Al, **3528**
Lindberg, A., H. Neuert and H. Weidner, resonance in electrodeless h.f. gas discharge in magnetic field, **85**
Lindberg, O., Hall and related effects, **713, (C)1975**
Lindblad, B. A., radar investigation of 1950 δ-Aquarid meteor shower, **1320**
Lindell, A., and G. M. Wells, crystal valves, **264**
Lindeman, R. J., and C. E. Dean, tuner for u.h.f. television band, **1166**
Lindemann, W. W., and A. van der Ziel, flicker noise caused by interface layer, **1531**
Lindquist, R., ionizing effect in E layer near sunrise, **1346**; 16-kW panoramic ionospheric recorder, **3052**; polar blackouts recorded at Kiruna observatory, **3094**
Lindsay, P. A., and G. D. Sims, application of thermodynamics of irreversible processes to magnetron theory, **2847**
Lindström, G., with H. Atterling, 225-cm cyclotron at Stockholm, **506**
Ling, T. T., c.r.o. display of aerial radiation patterns, **3069**
Linke, J. M., variable time-equalizer for video-frequency waveform correction, **1178**
Linvill, J. G., transistor negative-impedance converters, **2582**
Linvill, W. K., sampled-data control systems, **3722**
—— and J. M. Salzer, analysis of control systems involving digital computers, **3075**
Lipinski, J., with others, microwave techniques for communication links, **219**
Lippel, B., high-precision analogue-to-digital converter, **450**; inter-conversion of analogue and digital data for measurement and control systems, **2365**
Lippert, G. D., and others, radio interference tests in field and laboratory, **2431**
Lippert, W., and W. Pohlit, electron-optical properties, of e.s. lenses, **795**
Lippert, W. K. R., representation of standing waves in acoustic impedance tube, **2867**
Little, C. G., and A. Maxwell, scintillation of radio stars during aurorae and magnetic storms, **396**
Little, V. I., standing-wave method for absorption measurements in polar liquids at 3 kMc/s, **2066**
Littmann, M. F., ultrathin magnetic-alloy tapes, **760**
Livingston, D. C., colour television, colorimetric analysis of systems of, **1816**, synchronous demodulator in N.T.S.C. receiver, **3129**
—— with R. M. Bowie, N.T.S.C. colour-television transmission system, **3124**
Livingston, M. S., with others, strong-focusing synchrotron, **1454**, origin of, **3678**
Livingston, R. S., Oak Ridge 86-in. cyclotron, **181**
Lloyd, L. H., narrow-band spectrum analysis of p.p.m. signal, **470**
Lo, A. W., transistor trigger circuits, **651**
Lobanov, E. M., with others, action of electron stream on current sensitivity of Se and Ag_2S photocells, **3140**
Locher, H., h.f. measurement methods in textile industry, **177**
Lochner, J. P. A., and A. Semmelink, electroacoustics laboratory at School for the Deaf, Worcester, C.P., **3**
Lockhorst, D. A., with others, influence of magnetic field on resistance of Fe films, **1039**
Lode, T., with J. D. Goodell, multistable magnetic digit-storage devices, **449**
Lodén, L. O., with Y. Öhman, sunspots, flares, etc., observed at Stockholm in 1950 and 1951, **715**
Loeb, J., nonlinear servomechanisms, **831**, with filters, transients in, **1130**; information theory, applications to telecontrol and measurements, **1481**, London conference, Sept. 1952, on applications of, **3601**
—— with G. Cahen, pull-in of nonlinear oscillators with filtered output, **972**; calculation of attenuation in filtered oscillators, **2449**
Loeb, L. B., secondary processes in breakdown of gases, **997**
Loferski, J. J., infrared transmission of Te single crystals, **417**
Löfgren, L., analogue computer for solving algebraic equations, **3044**
Lohman, R. D., complementary-symmetry transistor circuits, **3519**
—— with others, c.r. tube plots transistor curves, **1437**; transistor circuits for television, **2813**
Lombardi, P., Heaviside, Vaschy, Pupin and some others, **(D)2561**
London, A., with others, long-tube method for determination of sound absorption, **13**
Loofbourrow, K. E., and C. M. Morris, stable oscillators for u.h.f. television receivers, **900**
Looser, R. C., with C. W. Goodchild, measurement of phase delay in television transmission circuits, **1750**
Loosjes, R., with C. G. J. Jansen, velocity distribution of electrons of pulsed thermionic emitters, **2837**; graphs for calculation of work function of thermionic emission, **3583**
Loper, G. B., with others, instrumentation for geophysical exploration, **2749**
Lopukhin, V. M., and V. S. Nikol'ski, e.m. properties of plane grating, **3588**
—— with E. I. Vasil'ev, theory of helix-type travelling-wave valve, **3453**
Lord, A. V., standards converter for international television, **3432**
—— and C. B. B. Wood, variable-definition camera channel for appraisal of television standards, **1753**
Lord, H. W., turns index for pulse-transformer design, **(A)1250, 3500**
Lord, K. M., mechanized dip-soldering of television receivers, **2710**
Lorrain, P., with E. Everhart, Cockcroft-Walton voltage-multiplying circuit, **2151**
Loshakov, L. N., theory of wave propagation in electron beam, **382**
Loughlin, B. D., improvements in dot-sequential colour television systems, **(A)240**
Loughren, A. V., N.T.S.C colour-television signal, **2465**
Lovell, A. C. B., with others, velocity distribution of sporadic meteors, **1009**
Lovell, G. H., with others, amplifiers for L3 coaxial-cable system, **3411**
Lovelock, R. T., Ge rectifiers in television receivers, **1505**; Ge crystal valves, **1515**
Lowry, W. R. H., and W. N. Genna, independent-sideband s.w. receiver, **2425**
Lubchenko, A. F., with A. E. Glauberman, dielectric properties of $BaTiO_3$, **3011**
Lucas, D. H., properties of semiconducting ceramic glaze, **438**
Lucas, L., conductivity of ionosphere and geomagnetic tides, **2312**
Lucas, R. T., with others, electrical properties of glass-fibre paper, **1719**
Lucas, W. P., with H. E. Holman, continuous-motion system for televising motion-picture films, **851**
Luck, D. G. C., with G. H. Brown, principles and development of colour-television systems, **3428**
Ludeke, C. A., and C. L. Morrison, analogue computer for nonlinear differential equations, **2372**
Lüdi, F., influence of plasma oscillation in transit-time valves, **1525**; turbator, **2518**; inverted magnetron, **(D)2849**
Lueck, L. B., and W. W. Wetzel, performance of high-output magnetic tape, **1576**
Lueg, H., and E. Oberhausen, sawtooth-current generator for recording of time intervals, **152**
Lufcy, C. W., A. E. Schmid and P. W. Barnhart, improved magnetic servo amplifier, **(A)3724**
Luftman, A. S., with R. C. Hergenrother, improved single-gun storage c.r. tube, **1868**
Lugeon, J., radiosonde observations of wind by pulse equipment without responder, **2993**
Lummis, F. L., with others, capacitance effects in thin conductive films, **2682**
Lundquist, S., studies in magneto-hydrodynamics, **1660**
Lusby, W. S., with others, phosphor-photocell radiation detector, **1103**
Luscombe, G. W., television aerials, **1590**
Lüst, R., r.f. line emission of interstellar material, **96**
Lutz, S. G., transmission-line load impedance for maximum efficiency, **2219**
Lyon, J. A. M., and T. J. Dunsheath, correlation of temperature and electric-field strength during dielectric heating, **590**
Lyons, H., with others, microwave absorption spectrum of ND_3, **2298**

Ma, Min-Yuan, with others, stability of control systems, **1489**
Macdiarmid, I. F., 'sine-squared' pulse generator for testing television links, **1089**
MacDonald, A., with others, evaporation of Ge films from carbon crucible, **3032**
MacDonald, A. D., h.f. breakdown in Ne, **702**
MacDonald, D. K. C., and K. Sarginson, galvanomagnetic effects in conductors, **1974**
MacDonald, H. B., with K. E. Latimer, possible applications of ferrites, **1396**
Macek, O., measurements on television receivers, **2397**
Macelloni, —, and — Vannel, control towe s for civil aviation, **3419**
Machin, K. E., and F. G. Smith, occultation of radio star by solar corona, **98**
Macht, H. G., two-dipole model for main geomagnetic field and its secular variation, **1012**

World Radio History

MacKay, R. S., interesting nonlinear effects, 2273
Mackenzie, K. A., with L. R. Hulls, electronic h.v. insulation tester, 480
MacKnight, M. L., with R. L. Chasson, ethylene and ethyl alcohol as quenching agents in external-cathode G-M counters, 2105
Macmullen, A., with others, nonlinear filtering and wave-shape multiplexing, 670
Macnamara, T. C., with N. Collins, electronic camera in film making, 1830
MacNaughton, M. M., properties of aperture electron lenses, 188
Macnee, A. B., high-speed product integrator, 2058
Macpherson, A. C., with R. W. Beatty, mismatch errors in microwave power measurements, 3661
Madelung, O., and H. Welker, theory of mixed semiconductors, 2028
Maecker, H., wave-theory calculation for total reflection, 1006
Maeda, K., Y. Aono and T. Kobayashi, graphical calculation of h.f. sky-wave field strength, 2777
—— with M. Hasegawa, conductivity of upper atmosphere deduced from diurnal variations of geomagnetic field, 2647
Mager, A., influence of grain size on coercive force, 2341
Magnus, W., infinite matrices associated with diffraction by an aperture, 2625
Maillard, J., application of information theory to telecommunications and radar, 1792
Maire, J., deterioration of propagation conditions since Aug. 1950 on Paris-New York decametre-wave circuit, 202
Makedonski, V. L., with A. R. Shul'man, secondary emission from dielectrics under single-pulse conditions, 3008
Malakhov, L. N., with S. M. Rivkin, effect of oxygen on PbS photoresistors, 3040
Malan, D. J., air discharges and positive charge at bottom of thundercloud, 1683
Malatesta, S., statistical study of communications, 819
Malsch, F., Type-C3m amplifier pentode, 589
Malsch, J., and H. Beneking, transistor properties and circuits, 44
—— and F. W. Dehmelt, apparatus for drawing Ge single crystals, 2707
Maltby, F. L., design of d.c. null detector, 3665
Malter, L., with E. G. Ramberg, potential distribution between accelerating grid and parallel anode, 1534
Malyavkin, L. P., with L. A. Vainshtein, alternating component in photocurrent under strong illumination, 3138
Mandel, P., slightly delayed projection of television pictures, 241, 1155; reversible process for recording on and reproduction from cinematograph films, 3125
Mankin, A. H., corona-suppression methods, 1306; interference effects in magnetic recording heads, 2876
Manning, L. A., determination of vertical distribution of electron density in ionosphere, (D)1997
—— O. G. Villard, Jr, and A. M. Peterson, double-Doppler investigation of meteor-trail echoes, 393
—— with others, transmission by reflection from meteoric ionization, 2117
Mansfield, R., and S. A. Salam, electrical properties of molybdenite, 2708
Mansfield, W. V., with others, ground-to-air cochannel interference at 2·9 kMc/s, 1798
Mantz, M. R., with others, Type E80T valve, synchronization of v.f.o. with, 2816, multichannel I.G.O. circuits using, 2817
Maple, E., with others, 'dynamo' currents and conductivities in ionosphere, 1353
Mapleton, R. A., diffraction patterns for solid delay lines, 2574
Marchese, T. J., with others, recent developments in travelling-wave valves, 274
Marcuvitz, N., with L. B. Felsen, slot coupling of rectangular and spherical waveguides, 3193
Margolin, A. R., with others, a.f.c. of high-power klystrons, 2942
Mariani, F., electron density in upper atmosphere, 3598
Marique, J., response of a series of resonant circuits to e.m.f. whose frequency is a linear function of time, 1941; action of unlimited train of telegraphic signals on resonant *RLC* circuit, 3241
Markham, J. J., relations between energy and intensity in second-order acoustic fields, 2194
Markov, G. T., excitation of circular waveguide, 2564
Markow, G. R., with A. J. Hornfeck, multiplex telemetry system using teletype transmission, 1097
Marks, M., synchronizing signal clipper with unusual noise immunity, 252
Markus, J., and V. Zeluff, Electronics for Communications Engineers, (B)909
Marmo, F., with others, formation of D layer, 2652
Marshall, C. A., television converter, 2169
Marshall, J., with J. Fischer, Type-6BN6 gated-beam valve as fast coincidence counter, 512
—— with others, synchrocyclotron for 450-MeV protons, 1764
Marshall, J. F., theory of secondary emission, 705
Marshall, J. S., precipitation and lightning observed by radar, 2003
Martin, A., with A. Fréon, simple mains-frequency pulse generator, 488
Martin, D. L., and A. H. Geisler, permanent-magnet properties of Co-Pt alloys, (D)2709
Martin, J. R., and C. F. Schunemann, measurement of λ in mm, 2384
Martin, L. H., ionospheric-disturbance forecasting, 3283
Martin, P. N., transient conditions in transformers feeding half-wave rectifier circuit, 3501
Martin, R. E., with others, reduction of loss in ferrite gyrators, 1610
Martindale, J. P. A., lens aerials at cm λ, 3203
Martinet, J., conduction mechanism in semiconductor complexes, 114
Marton, L., J. A. Simpson and J. A. Suddeth, electron-beam interferometer, 3074
Martyn, D. F., geo-morphology and F_2-region storms, 1673; morphology of ionospheric variations associated with geomagnetic disturbance, 3301
Martyn, D. F., with W. G. Baker, conductivity of ionosphere, 1352
Marutake, M., effect of electric field on domain structure of Rochelle salt, 2050
Mary, M., with others, electronic tachometer, 2747
Marziani, M., propagation of wave front in dispersive medium, 390, 1007
Mason, R. W., with others, precision phase comparator for l.f., (A)483, 1080
Mason, S. J., feedback theory and properties of signal flow graphs, 3531
Mason, W. P., properties of a tetragonal antiferroelectric crystal, 1045
—— and B. T. Matthias, properties of deuterated ADP, 1044
—— W. H. Hewitt and R. F. Wick, modulators and gyrators using Hall effect in Ge, 1930
Massey, H. S. W., recombination of gaseous ions, 999
Masson, F. Y., high-speed d.c. amplifier, 1090
Masucci, C., with others, Ge diode as video detector, 2475
Mataré, H. F., blocking-layer interaction in and fluctuation statistics for transistrons, 586; harmonic mixing with crystal diodes, 1791
Matheson, R. M., and L. S. Nergaard, decay and recovery of pulsed emission of oxide-coated cathodes, 285
Mathews, K. C., and R. C. Boe, application of nonlinear techniques in servomechanisms, 3111
Matossi, F., effect of electric field on continuously excited phosphor, 2284
—— and S. Nudelman, influence of electric fields on luminescence, 2283
Matschinski, M., application of Maxwell's equations for 3-layered media to theory of movement of magnetic storms, 100
Matthaei, G. L., filter transfer-function synthesis, 1611
Matthias, B. T., with W. P. Mason, properties of deuterated ADP, 1044
Mattson, R. H., and A. van der Ziel, shot noise in Ge filaments, 2035
Maue, A. W., with H. Hönl, uniqueness of solutions in rigorous theory of diffraction, 373
Maurer, P., with H. Ebel, new sound chamber of Technische Hochschule, Karlsruhe, 1889
Mawardi, O. K., variational principle in acoustics, 2857
Maxwell, A., with C. G. Little, scintillation of radio stars during aurorae and magnetic storms, 396
Maxwell, D. E., measuring nonlinear distortion in a.f. equipment, 2735
May, A. S., test equipment for the TD-2, 3063
Mayaud, P. N., magnetic field in Adélie Land, May 1951–Jan. 1952, 2305
Mayo, B. J., with A. F. Pearce, Type-R5081 reflex klystron oscillator for f.m. at cm λ, 1214
Mayot, M., with É. Argence, calculation of true heights of ionospheric layers, taking account of geomagnetic field, 3290
McAuslan, J. H. L., dekatron c.r.o. time marker, 771
McCaig, M., preferred direction in permanent-magnet alloy, 2342
McCain, C. E., with others, single synthetic CdS crystals, 135
McConnel, E. D., c.r.-tube projector for large-screen cinema television, 1835
McCreary, H. J., magnetic-cross valve and applications, 3502
McCreary, R. L., W. J. Armstrong and S. C. McNees, axial-flow u.h.f. resnatron, 1208
McCue, C. G., Green's reinterpretation of magneto-ionic theory, 3392
McDonal, F. J., Fourier analyser, 2719
McDuffie, G. E., Jr., pulse duration and repetition rate of transistor multivibrator, 682
McElwee, E. M., with M. A. Acheson, reliability of valves, 271
McGhee, H., with R. Theile, secondary-electron multipliers in image iconoscopes, 855
McGregor, R. B., synchronous demodulator for colour television, 253
McGuire, W. S., and A. G. Bird, radio bearer equipment for carrier telephone systems, 3412
McIntosh, D. H., solar and terrestrial relations, 1983
—— with R. P. W. Lewis, diurnal and storm-time geomagnetic and ionospheric variations, 3300
McIntosh, R. O., hermetic seals, 2356
McKeag, A. H., with others, phosphors for television c.r. tubes, 1869
McKenzie, A. A., modern a.m. broadcasting transmitter, 3746
McKinley, D. W. R., and P. M. Millman, long-duration echoes from aurora, meteors and ionosphere, 2000
McKune, W. J., and M. F. Brust, subharmonics in series nonlinear circuit, 2929
McLachlan, K. R., and R. Yorke, objective testing of pickups and loudspeakers, 19
McLean, F. C., television modulation, (D)1163
McLeod, T. S., with others, circuit technique for f.m. microwave links, 220
McMahon, M. E., with N. H. Enenstein, pulse response of junction transistors, 3514
McMahon, W., with others, polyethylene terephthalate as capacitor dielectric, 440
McMullan, D., scanning electron microscope, 1768, for opaque specimens, 3382
McNees, S. C., with others, axial-flow u.h.f. resnatron, 1208
McNicol, R. W. E., with others, ionosphere measurements at oblique incidence over eastern Australia, 807
McQueen, J. G., Type-500 monitor for high-speed recurrent waveforms, 482
McQuistan, R. B., determination of resistance/temperature characteristics of bulk semiconductors, 3614
McVay, M. S., with J. D. Ryder, thermocouple a.f. wattmeter, 2394
Meade, J. E., with A. E. Hastings, device for computing correlation functions, 161
Meahl, H. R., and C. C. Allen, calibrating ammeters at frequencies > 100 Mc/s, 1075
Medicus, G., with G. Wehner, probe measurements in hot-cathode gas diodes, 381
Medkeff, R. J., and R. J. Parent, diode-bridge limiter for analogue computers, 2367
Meerkamp van Embden, H. J., with others, steel c.r. tube for television receivers, 3132
Megaw, E. C. S., e.m. waves and fluctuations, 1105

World Radio History

Megla, G., external effects on u.h.f. resonators, **2932**
Meier, R., and K. Schuster, sound-wave propagation in piezoelectric crystals, **3014**
Meierdiercks, D. R., with H. Greenberg, ground-reflection phase-error characteristics of vertical aerial, **2221**
Meinke, H. H., graphical calculation of pass band of two-stage wide-band filters, **57**; designation of waves in waveguides, **2217**; modified exponential-line impedance transformer, **3533**
Meinshausen, G., with L. Pungs, magnetic demodulation, **3400**
Mellen, R. H., thermal-noise limit in underwater sound-signal reception, **106**
Melling, W. P., phase shifter for range 10–100 Mc/s, **3357**
Melotte, P. J., with H. Spencer Jones, harmonic analysis of geomagnetic field for epoch 1942, **3279**
Melville, W. S., magnetic modulators for pulsed radar, **2992**
Mendousse, J. S., nonlinear dissipative distortion of progressive sound waves, **1553**
Mengel, J. T., p.p.m. telemetry systems for rockets, **2404**
Mentzer, J. R., dielectric lenses in model measurements of radar echoing areas, **1366**
Menzel, D., with R. Kollath, measurement of charge on moving electrons, **2958**
Menzer, E., with K. Sittel, improved radiosonde, **497**
Meos, J., with G. Hellgren, location of aurorae with 10-m radar equipment, **728**
Mercier, J. M., and R. P. Musson-Genon, Si crystal detectors, **2190**
Merrithew, R. F., noise meter for production testing of transistors, **2385**
Mertz, P., influence of echoes on television transmission, **3441**
Merz, W. J., domain properties of $BaTiO_3$, **759**
Mesnard, G., thermionic properties of thoria, **2506**; thoria cathodes. **2507, 2508, 2840**, measurements relating to the filament of, **3151**
Messent, S. W., with A. N. Hawthorn, laminated plastic insulating materials, **2353**
Met, V., and E. Skudrzyk, small apparatus using $BaTiO_3$ oscillator for ultrasonic testing of materials, **1756**
Mette, H., and H. Pick, electronic conductivity of anthracene single crystals, **3016**
Meunier, R., and M. Bonpas, enamel seal for thin mica windows, **3638**
Meyer, A. J. P., and P. Taglang, influence of magnetic field on polymorphic transformation in a ferromagnetic material, **2339**
Meyer, E., and L. Bohn, sound reflection at surfaces with periodic structure, **1895**
—— and H. G. Diestel, room-acoustics investigations with directive transmitters and receivers, **12**
—— and H. Oberst, resonance-type absorbers for water-borne sound, **308**
—— and K. Tamm, wide-band absorbers for liquid-borne sound, **1569**
Meyer, R., with S. Paksweer, arc drop and deionization time in inert-gas thyratrons, **3154**
Meyer de Stadelhofen, J., suppression of interference, caused by railway systems, **2131**, from fluorescent lamps, **2133**
Meyer-Eppler, W., communications research, **1479**; report on symposium on applications of communication theory, **2432**
Meyerhoff, A. A., and R. Graham, Jr, fixed-length transmission lines as circuit elements, **1272**
Michaels, E. L., loci of complex impedance and admittance functions, **2248**
Michard, R., physical conditions in sunspots deduced from spectral data, **1324, 1669**
Michels, W. C., and R. C. Barbera, frequency-eliminating transconductance bridge, **59**
Middleton, D., statistical criteria for detection of pulsed carriers in noise, **2782, 2783**
Mikhnevich, M. N., with others, coercive force of nonuniformly magnetized specimens, **3024**
Mildner, R. C., developments in h.f. transmitter cables, **2210**
Mileikowsky, C., and R. T. Pauli, 1·5-MV accelerator for heavy particles, **508**
Miles, J. G., magnetic amplifiers, types of, **2911**, bibliography on, and on saturable-reactor art, 1887 to mid-1951, **3505**
Miles, J. W., acoustic diffraction at aperture in plane screen, **1881**
Miles, R. C., design of voltage-regulator-tube circuits, **231**
Miles, V. G., radar echoes and lightning, **107, 3306**
Miller, B. L., multicavity linear electron accelerator, **509**
Miller, C., with J. E. Lilienfeld, conductivity distribution within dielectric films on Al, **3528**
Miller, C. D., and A. Scharf, isotransport camera for 100 000 frames/sec, **2058**
Miller, C. F., with J. W. Gibson, electric strength of SF_6 at r.f., **3627**
—— with Y. A. Omar, characteristic impedance of rectangular coaxial transmission lines, **3474**
—— with others, r.f. properties of 16 insulating materials, **1716**
Miller, E. J., gramophone-pickup pre-amplifier, **315**
Miller, M., B. L. Waddell and J. Patmore, digital to analogue converter, **148**
Miller, R., with others, synchrocyclotron for 450-MeV protons, **1764**
Miller, S. E., and A. C. Beck, low-loss waveguide transmission, **1585**
Miller, T., r.f. field quenching of phosphors, **1370**
Millman, G. H., ionospheric winds, measurements at 150 kc/s, **720**, study of, **1676**
—— with others, heights of ionospheric winds determined from long-wave measurements, **2311**
Millman, P. M., with D. W. R. McKinley, long-duration echoes from aurora, meteors and ionosphere, **2000**
Millman, S., spatial-harmonic travelling-wave amplifier, **1187**
Mills, B. Y., positions of six sources of cosmic r.f. radiation, **717**
Mills, R. A., with A. J. Biggs, performance of television receiver installations in presence of interference, **1511**
Mills, R. L., with others, instrumentation for geophysical exploration, **2749**
Milnes, A. G., 3-phase transductor circuits for magnetic amplifiers, **949**
—— and C. S. Hudson, 400-c/s and 1·6-kc/s transductors, **3216**
—— and T. V. Vernon, saturable-core reference source for magnetic amplifiers, **2237**
Milwright, A. L. P., with L. S. Le Page, radar and ice, **2673**
Min-Yuan Ma. See Ma, Min-Yuan.
Minnis, C. M., E region during solar eclipse, 25th Feb. 1952, **1675**; ionospheric-storm-warning services, **2110**; longitude effect in F region, **(D)2307**; value of forecasts, **(D)2767**
Minorsky, N., oscillators including elements having inertia, **68**
Miquel, R., ionophone applied in ultrasonics, **2539**
Missen, J. I., push-pull transistor amplifiers, **3521**
Mitchell, D. W., with others, fundamentals of glass-to-metal bonding, **2712**
Mitchell, E. W. J., with L. D. Brownlee, variations of lattice parameters of semiconducting oxides, **115**
Mitchell, J. H., recent developments in vibrators and vibrator power packs, **228**
Mitoff, S. P., with others, fundamentals of glass-to-metal bonding, **2712**
Mitra, A. P., study of ionosphere by means of extraterrestrial radio waves, **1674**
Mittelmann, L. W., television test equipment, **2396**
Miya, K., and N. Wakai, characteristics of ionospheric disturbances during severe magnetic storms, **2987**
—— T. Kobayashi and N. Wakai, field strength of scattered waves in r.f. propagation, **2775**
—— T. Murata and H. Wada, propagation characteristics of obliquely incident pulse waves during solar eclipse 9th May 1948, **2770**
—— S. Ouchi and S. Kanaya, attenuation characteristics for h.f. and m.f. waves, and application to field-strength calculations, **2774**
—— with others, frequency of occurrence of fE_s and $fmin$F, **2985**
Miyazawa, H., photoelectric emission and energy structure of Cs_3Sb, **3004**
—— and S. Fukuhara, electrolytic conduction in Cs_3Sb, **2676**
—— and others, composition of Cs-Sb photocathodes, **2824**
Moats, R. R., mode interactions in magnetrons, **593**
Mode, D. E., coaxial-line filters, **669**
Mohrmann, J., German v.h.f. harbour radio, **1487**; tracking problem in superheterodyne receivers, **2126**
Mol, G., 220-Mc/s oscillator with TBW-6/6000 or TBL-6/6000 transmitting valve, **2270**
Mole, J. H., Filter Design Data for Communication Engineers, **(B)1955, (B)2280**
Moles, A., 3-dimensional representation of complex musical tone, **1219, 3462**
Möllenstedt, G., chromatic losses of electrons in passage through matter, **704**
—— and H. Düker, emission-microscope surface images obtained with electrons due to oblique bombardment by ions. **2757**
Möller, H. G., transformer-coupled resonance galvanometer, **2388**
Monelli, R., input impedance of line, **1579**
Montgomery, H. C., noise in semiconductors, **122**; transistor noise in circuit applications, **643**
Montroll, E. W., with G. F. Newell, theory of Ising model of ferromagnetism, **2964**
Moon, J. H., errors in m.f. direction finding in aircraft, **414**
Moon, P., and D. E. Spencer, coordinate systems associated with elliptic functions, **3347**
Moore, A. D., correlative property of 2-dimensional fields, **3573**
Moore, A. R., with others, use of flying-spot scanner to study photosensitive surfaces, **890**
Moore, R. C., J. F. Fisher and J. B. Chatten, colour characteristics of flying-spot signal generator, **2807**
Moore, R. P., Jr, with others, transistor oscillators, **45**
Moore, R. W., industrial applications of 'Magamps', **1095**
Morene, T., with R. L. Jepsen, f.m. distortion in reflex klystrons, **1545**
Morgan, C. G., with F. L. Jones, surface films and field emission of electrons, **3267**
Morgan, E. R., with G. R. Piercy, ferromagnetism and order in Ni-Mn alloys, **3025**
Morgan, G. D., errors in diode-valve voltmeters, **780**; h.f. discharges in gases, **1961**
Morgan, K. A., with C. F. White, dual-input parallel-T network, **3537**
Morgan, M. G., review of v.h.f. ionospheric propagation, **2422**
Morgan, S. P., Jr, theory of laminated transmission lines, **25, 618**
Morgulis, N. D., and Ya. P. Zingerman, investigation of oxide cathode, **1527**
Morilleau, É., H. Dormont and R. Champeix, photomultipliers for counting scintillations, **2181**
—— with H. Dormont, photomultipliers and detection of nuclear particles, **3748**
Morita, S., probe method of measuring ultrasonic field, **2195**
Moriyama, F., sunspots and magnetic storms, **2641**
—— with T. Hatanaka, characteristics of noise storms, **2971**
Morrill, C. D., and R. V. Baum, diode limiters simulate mechanical phenomena, **448**; stabilized electronic multiplier, **3643**
Morris, C. M., with K. E. Loofbourrow, stable oscillators for u.h.f. television receivers, **900**
Morris, D. W., with W. J. Bray, s.s.b. multichannel operation of s.w. radio links, **2144**
Morris, G. W., and P. G. M. Dawe, band-pass filter for 8–13 c/s, **3237**
Morris, L. H., G. H. Lovell and F. R. Dickinson, amplifiers for L3 coaxial-cable system, **3411**
Morrison, C. L., with C. A. Ludeke, analogue computer for nonlinear differential equations, **2372**
Morrison, H. J., with L. F. Deise, high-power a.f. amplifiers, **2948**
Morrow, W. E., with others, wide-band data transmitter. **3559**
Morse, E. W., with others, c.r. tubes with internal pole pieces, **257**
Morse, R. W., acoustic propagation in granular media, **923**

World Radio History

Morser, A. H., Sunbury portable frequency substandard for 100 c/s to 100 kc/s. **3070**
Morton, G. A., with others, two new photomultipliers for scintillation counting, **266**
Morton, J. A., present state of transistor development, **873**
Moses, H. E., application of Schwinger's variational principle to Dirac's equation of electron, **2626**
—— and Ta-You Wu, dissociation of O_2 in upper atmosphere, **102**
Moss, F., with others, aerial-radiation-pattern analogue computer, **3198**
Moss, H., impulse modulator, **2177**; recurrent-sweep chronograph, **3068**
Moss, T. S., interrelation between optical constants of PbTe and Si, **2017**; Photoconductivity in the Elements, **(B)2358**
Mostafa, A. E. S., and M. K. Gohar, determination of parameters of single-layer coils, **1922**
Mostovetch, N., electrical conductivity of very thin evaporated metal films, **3031**
Mott-Smith, H. M., change of electron temperature in electron beam, **2493**
Motz, H., W. Thon and R. N. Whitehurst, radiation by fast electron beams, **3582**
Motzo, M., interaction between e.m. waves incident vertically on the ionosphere, **2111**
Moulon, J. M., semiconductors and applications, **427**; properties and utilization of transistors, **1851**
Moussiegt, J., lattice lenses for cm waves, **1595**
Moyano Reina, F., losses in aerial feeders, **2211**
Moynihan, J. D., with R. C. Cheek, carrier-frequency noise on power lines, **3705**
Mueller, C. W., with others, Ge *p-n-p*-junction transistor, **876**
Mühleisen, R., with A. Ehmert, high-resistance direct-voltage valve voltmeter for ± 500 V, **2078**
Mullaney, F. C., design features of ERA 1101 computer, **1414**
Müller, E. W., with M. Drechsler, field electron emission of crystal surfaces, **1963**
Müller, H., comparison of double-tone and intermodulation methods of distortion measurement, **163**
Müller, J., square-wave testing of television transmission systems, **1754**; relation between transient response and picture quality, **3745**
Müller, L., architectural acoustics of Cologne broadcasting centre, **3468**
Müller, M., electron optics of long-beam amplifier valves, **2827**
Müller, R., and E. Ruch, e.m. self-oscillations in rectangular cavity with finite wall conductivity, **67**
Müller, Reinhard, radiation resistance of straight wire, **1588**; absorber for e.m. waves, **2796**; e.m. waves in circular-section cylinders, **3555**
Müller, Rolf, diffraction of guided waves, at plane diaphragms, **625**, by diaphragms with slits, **1583**, **2566**; correlation of geomagnetic M-storms with monochromatic corona, **2975**
—— and K. Westpfahl, diffraction of e.m. waves by slit, **1971**
Müller, W., Siemens u.s.w. and television transmitting valves, **1535**
Mulvey, T., 1952 conference of German Society for Electron Microscopy, **190**; magnetic circuit in electron-microscope lenses, **3385**
Mumford, A. H., with G. R. M. Garratt, history of television, **848**
Mumford, W. W., optimum piston position for wide-band coaxial-to-waveguide impedance matching, **1260**
Munakata, K., some exact solutions in nonlinear oscillations, **2622**
Muncey, R. W., with A. F. B. Nickson, acoustic-impedance measurement by transmission-characteristic method, **2868**; reverberation times of Australian concert halls, **3176**
Munford, C. M., with P. C. Clemmow, table of values of wave-theory function for complex arguments, **444**
Muniz, R., with V. Trad, theatre projection television equipment, **562**
Munro, G. H., diurnal variation of direction of travelling disturbances in ionosphere, **2309**
Munsch, M., with B. Bartels, 'conductron' photoconductive camera tube, **3128**
Murata, T., with others, propagation characteristics of obliquely incident pulse waves during solar eclipse 9th May 1948, **2770**
Murden, W. P., with A. W. Dickson, vibrating-wire high-Q resonator, **3561**
Murdock, C. E., with others, high-power klystrons, **1213**
Murphy, B., distributed amplifiers, **1284**
Murray, D. M., and N. L. Kusters, electromechanical a.c. line-voltage stabilizer, **3726**
Murray, R. L., and L. T. Ratner, electric fields in cyclotron dees, **1765**
Müser, H., and H. Schilling, thermoelectric measurements on Cu_2O, **3613**
—— with R. Caspary, photoconductivity of CdS crystals at relatively high temperatures, **1687**
—— with L. Genzel, photoelectric and optical properties of PbS layer, **2677**
Musgrave, J. R., with A. P. Thompson, production, properties and applications of Ge, **1405**
Musson-Genon, R. P., u.h.f. valves for 3-cm radar equipment, **588**
—— with J. M. Mercier, Si crystal detectors, **2190**
Myers, D. M., and W. R. Blunden, C.S.I.R.O. differential analyser, **1049**
Myers, G. T., and I. Newbiggin-Watts, television studio at 1951 Radio Exhibition, London, **564**
Myers, H. P., secondary emission from Ag and Cu films for primary-electron energies < 10eV, **1658**; varying-capacitor method for measuring contact-potential difference, **3259**

Nagata, T., auroral-zone currents, **2648**; solar-flare type of variation of geomagnetic field and integrated conductivity of ionosphere, **2663**, **2666**; distribution of S.C.* of magnetic storms, **2973**
—— and N. Fukushima, constitution of polar magnetic storms, **2977**
—— and T. Oguti, ionospheric storms in the auroral zone, **3293**
—— and T. Suzuki, solar-flare type of variation of geomagnetic field and integrated conductivity of ionosphere, **2664**
—— and M. Tazima, solar-flare type of variation of geomagnetic field and integrated conductivity of ionosphere, **2665**
Nagata, T., with others, anomalous ionization over auroral zone during magnetic storms, **2991**
Nail, J. J., design of discone aerials, **3196**
Nakada, I., with others, hysteresis loops of $BaTiO_3$ ceramic at h.f., **3012**
Nakata, Y., effects of solar eclipse on F regions, 9th May 1948, **2658**
—— M. Kan and H. Uyeda, frequency-sweep $h'F_2$ measurements, **3297**
Nalos, E. J., with others, debunching of electron beams constrained by strong magnetic fields, **3459**
Nalot, J., with others, natural oscillations and mode changes in multi-cavity magnetrons, **1543**
Namiki, M., and K. Horiuchi, transient phenomena in waveguide, **2216**
Nankivell, J. F., method of observing selected areas in electron microscopes, **3080**
Napolin, S., with H. Fogel, cavity tuner for u.h.f. television, **1506**
Narayan, N., and K. S. Prabhu, production of standard waveforms with 3-MV impulse generator, **974**
Narita, S., Nijboer theory for BaO and co-existence of various impurity levels, **2504**; thermionic emission and electrical conductivity of oxide-coated cathodes, **3455**
Navon, D., R. Bray and H. Y. Fan, lifetime of injected carriers in Ge, **740**
Neale, D. M., with R. J. Hercock, exposure timers compensated for supply-voltage variations, **789**
Nearhoof, H. J., with others, polarization of vertically incident long radio waves, **806**
Nechleba, F., extension of concept of time constant, **2575**
Nedoluha, A., and K. M. Koch, mechanism of resistance variation in magnetic field, **377**
Néel, L., antiferromagnetism and ferrimagnetism, **1000**
Neeteson, P. A., flywheel synchronization of timebase generators, **2479**, **2480**
—— with others, ECL80 and EQ80 valves in flywheel synchronizing circuits, **2168**
Negishi, K., with Y. Torikai, phase method of visualizing ultrasonic waves, **2865**
Neiswander, R. S., with others, linear-to-logarithmic voltage converter, **3042**
Nelson, E. H., and W. A. Price, discharge lamps for television studios, **866**
Nelson, R. B., magnetrons for dielectric heating at 915 Mc/s, **2850**
Neppiras, E. A., high-frequency reciprocating drill, **2085**
Nergaard, L. S., studies of the oxide cathode, **1528**
—— with R. M. Matheson, decay and recovery of pulsed emission of oxide-coated cathodes, **285**
Nertney, R. J., model of lower E and D regions as deduced from long-wave measurements, **2306**
—— with J. J. Gibbons, wave-equation solution for ionospherically reflected long waves, **(D)410**, **517**
—— with others, polarization of vertically incident long radio waves, **806**; heights of ionospheric winds determined from long-wave measurements, **2311**
Nestel, W., and E. Schwartz, principles for planning of u.s.w. broadcasting systems, **2789**
Neuert, H., and H. Gutbier, counter tubes with Ar and methylene-halide filling, **1461**
—— with others, resonance in electrodeless h.f. gas discharge in magnetic field, **85**
Neugebauer, H. E. J., new method of solving diffraction problems, **1295**
Newbiggin-Watts, I., with G. T. Myers, television studio at 1951 Radio Exhibition, London, **564**
Newell, G. F., and E. W. Montroll, theory of Ising model of ferromagnetism, **2964**
Newman, H. L., with W. K. Squires, video amplifiers with optimum transient response, **3133**
Newman, M. M., R. C. Schwantes and J. R. Stahmann, aircraft radio-interference measurements, **2075**
Newton, A., push-pull amplifiers for increased video output, **3743**
Newton, G. C., Jr., compensation of feedback-control systems subject to saturation, **1135**
Newton, G. C., and H. J. B. Atkins, application of television to demonstration of surgery, **1845**
Newton, H. E., electronic tracing head for oxygen cutting, **180**
Nexon, V. J., microwave relay systems in Europe, North Africa, Near East and Australia, **3108**
N'Guyen, Thien-Chi, and J. Suchet, voltage regulators using nonlinear elements, **230**
Nickson, A. F. B., accurate measurement of a.f., **1738**
—— and R. W. Muncey, acoustic-impedance measurement by transmission-characteristic method, **2868**; reverberation times of Australian concert halls, **3176**
Nicolet, M., effects of solar radiation in upper atmosphere, **1321**; collision frequency of electrons in ionosphere, **3299**
Nicolini, L., new dielectric material, **1048**
Nielsen, R., with N. Golden, c.r.o. for display of static characteristics of transistors, **784**
Nier, A. O., with E. G. Johnson, aberrations in sector-shaped e.m. lenses, **3680**
Niesel, W., dielectric constant of heterogeneous mixtures, **1693**
Niessen, K. F., condition for vanishing spontaneous magnetization below Curie temperature, **3337**
Nifontoff, N., flicker effect in crystal detectors, **1047**, **2189**; potential barrier between electrodes of same metal, **2628**
—— and M. Perrot, resistance of imperfect contact between two metals, **3258**
—— with A. Blanc-Lapierre, properties of potential barriers, **2629**
Niimi, T., contact-p.d. changes of Ge rectifier during forming, **3260**
Nijs, L. J., test set for recording impulses, **2379**
Nikol'ski, V. S., with V. M. Lopukhin, e.m. properties of plane grating, **3588**
Nill, —, h.f. transmitters for aerodromes, **3419**

World Radio History

Nilsson, S. G., motion of electrons in field of toroid, **383**
Nims, P. T., design criteria for automatic controls, **2450**
Nimura, T., and Y. Watanabe, effect of finite circular baffle on sound field of disk, **1555**
Niutta, A., smallest frequency separation permissible between radio-telegraph transmissions, **540**
Nixon, R. D., monoscope, **850**
Nobiuti Ikeno. See Ikeno, Nobiuti.
Noble, D. E., commercial experience with 160-Mc/s 20-kc/s split-channel equipment, **3708**
Noble, S. W., and P. J. Baxandall, design of d.c. amplifier based on second-harmonic type of magnetic modulator, **72**
Nödtvedt, H., magnetostriction and Δ-E effect in Ni, **1038**
Noga, K., and S. Kawamura, photoelectric emission from BaO, 2322
—— with others, composition of Cs-Sb photocathodes, **2824**
Nomura, Y., and T. Hatta, theory of linear aerial, **3201**
Nordby, K. S., amplifier noise particularly in a.f. range, **368**
Norde, L., network transformations, **2586**
Nordsieck, A., theory of large-signal operation of travelling-wave amplifiers, **2497**
Norton, K. A., transmission loss in radio propagation, **1111**
Noury, J., with A. Lacam, velocity of ultrasonic waves in Ar at pressures up to 950 atm, **1559**
Novak, W. D., printed multiconductor plug, **2239**
Novick, G., with others, high-power delay line for travelling-wave amplifier or oscillator, **2828**
Novosil'tsev, N. S., A. L. Khodakov and M. S. Shul'man, composition and properties of $BaTiO_3$ ceramics in strong fields, **3010**
—— with others, dielectric properties of $BaTiO_3$ single crystals, **3009**
Nowogrodzki, M., conductance measurements on operating magnetron oscillators, **157**; microwave equipment for magnetron production testing, **778**
Nuckolls, R. G., L. J. Rueger and H. Lyons, microwave absorption spectrum of ND_3, **2298**
—— with L. J. Rueger, Stark cell for microwave spectroscopy, **1317**
Nudelman, S., with F. Matossi, influence of electric fields on luminescence, **2283**
Nüscheler, M., evolution of electrical communication in Swiss army, **1118**
Nuttall, T. C., high-quality scanner for 35-mm film, **852**
Nutting, J., with others, conference on electron microscopy, Bristol, September, 1952, **1771**
Nyborg, W. L., acoustic streaming due to attenuated plane waves, **1551**

Obayashi, T., characteristics of F_2-layer storms, **2982**
—— with H. Uyeda, field-strength calculations for long transmission paths, **2778**
Oberbeck, H., pulse distributors, **2142**
Oberdorfer, G., definition of magnetic quantities, **1966**
Oberhausen, E., with H. Lueg, sawtooth-current generator for recording of time intervals, **152**
Oberst, H., with E. Meyer, resonance-type absorbers for water-borne sound, **308**
Ochsenfeld, R., antiferromagnetism, **706**
Odell, N. H., with others, grain-boundary barriers in Ge, **1406**
O'Dwyer, J. J., and R. A. Sack, frequency dependence of dielectric properties of dipolar substances, **1647**
Oehmichen, J. P., novel valve circuits, **2300**
Oelbermann, E. J., R. E. Skipper and W. J. Leiss, moisture aging of powder-core toroids, **2355**
Oettinger, A. G., programming digital computer to learn, **1415**
Offner, G., with A. Keil, production and testing of precious-metal coatings on insulating materials, **2052**
Ogle, W. E., with R. D. England, betatron monitor and integrator, **2754**
Oguti, T., with T. Nagata, ionospheric storms in the auroral zone, **3293**
Öhman, Y., and L. O. Lodén, sunspots, flares, etc., observed at Stockholm in 1950 and 1951, **715**
Okada, J., and T. Ikegawa, resistivity of artificial graphite, **1041**
Okamura, T., T. Fujimura and M. Date, permittivity and permeability of ferrites at 6·6-cm λ, **(C)1401**
Okazaki, A., H. Tubota and H. Suzuki, temperature dependence of zero-bias resistance of Cu_2O rectifiers, **3345**
Oldekop, W., capacitance of Se rectifiers, **1802**
Olin, I. D., X-band sweep oscillator, **973**
Olive, G. A., experimental 850-Mc/s television transmitter, **566**
Oliver, F. J., with W. F. Bonner, developments in metal rectifiers, **2154**
Olivier, R., h.f. generators for aircraft v.h.f. equipment, **3240**
Olson, A. B., with others, attenuation of wire helices in dielectric supports, **1523**
Olson, H. F., J. Preston and J. C. Bleazey, uniaxial microphone, **2199**
Omar, Y. A., and C. F. Miller, characteristic impedance of rectangular coaxial transmission lines, **3474**
O'Meara, T. R., and H. D. Webb, phase and gain stabilization in matched-channel receivers, **2320**
O'Neill, B. J., and A. Gutterman, equipment for transistor testing, **3053**
O'Neill, H. F., and L. L. Bailin, effects of dimensional errors on performance of linear shunt-slot arrays, **1592**
O'Neill, R., H. M. Thaxton and S. Cutler, autocorrelation function from ergodic hypothesis, **535**
—— with others, application of ergodic hypothesis in calculating auto-correlation function of teleprinter signals, **537**
Onishi, T., with M. Kikuchi, investigations of electrical forming of Ge rectifiers, **2932**
Opfer, G., with others, remanence in soft-iron circuits of magnetic electron lenses, **2102**
Oppitz, H., determination of linear quadripoles for cm λ, **1733**
Orchard, H. J., formulae for ladder filters, **666**
Ordung, P. F., and others, 3-terminal RC networks, cascaded, synthesis of, **656**, paralleled, synthesis of, **3536**
Ortusi, M., tropospheric propagation and analogies in wave mechanics, **2112**
Osborne, B. W., electron content of F_2 region below level of maximum ionization, **1349**
Osborne, F. J. F., activation of BeCu multipliers, **1517**
Osborne, M. F. M., number theory and magnetic properties of electron gas, **991**
Osche, R. A., developments in fixed resistors, **946**
Oser, E. A., R. O. Endres, and R. P. Moore, Jr, transistor oscillators, **45**
Osmond, W. P., magnetic properties of iron-oxide powders, **2338**
Ossaka, J., with Y. Kato, variation of geomagnetic field during bay disturbances, **2972**
Ostrow, S. M., and M. PoKempner, ionospheric critical frequencies and sunspot number, **1350**
Oswald, J., theory of antimetrical lattice filters, **2597**
Ota, M., recurrence tendency of magnetic storms, **2974**
Otpushchennikov, N. F., velocity of ultrasonic waves in solids, **1225**
Otte, J., with others, effects due to curvature of valve characteristics, **1854**
Ouchi, S., with others, attenuation characteristics for h.f. and m.f. waves, and application to field-strength calculations, **2774**
van Overbeek, A. J. W. M., and F. H. Stieltjes, bandwidth limit of junction transistors, **3747**
—— J. L. H. Jonker and K. Rodenhuis, decade tube for high counting rates, **3762**
Overhoff, G., programme-controlled computers in Germany, **1725**
Overton, B. R., with others, television valves and a.c./d.c. receivers, **1503**
Owen, F. C., and A. B. Ewen, transmitter drive unit for s.s.b. multichannel operation of s.w. radio links, **2175**
Owens, C. D., analysis of measurements on magnetic ferrites, **1707**
Owens, H. L., with A. Coblenz, temperature variation of transistor parameters, **883**; theory and applications of transistors, **1957, 2289, 2627, 3021, 3444, 3523**
Oxford, A. J., pulse-code modulation systems, **3106**

Packard, K. S., automatic Smith-chart plotter, **3065**
Packer, L., and W. J. Wray, Jr, Ge photodiodes read computer tapes, **454**
Padel, S. H., A. R. A. Rendall and S. N. Watson, test equipment for television transmission circuits, **1823**
Paetzold, H. K., vertical distribution of ozone, **2649**
Page, R. M., A. Brodzinsky and R. R. Zirm, microwave correlator, **1087**
Paivinen, J. O., and I. L. Auerbach, design of triode flip-flops for long-term stability, **3558**
Pakala, W. E., with others, radio interference tests in field and laboratory, **2431**
Pakswer, S., and R. Meyer, arc drop and deionization time in inert-gas thyratrons, **3154**
Paling, A. W. M., television transmission of Coronation ceremonies, **3118**
Palmer, L. S., dielectric constant of water in wet clay, **99**
—— A. Cunliffe and J. M. Hough, dielectric constant of water films, **1040**
Palmer, R. B. J., thermoelectric method for comparing ultrasonic field intensities, **3171**
Pan, Wen Yuan, one-channel converter for u.h.f. television, **861**
Panasyuk, E. I., with others, thermoluminescence of sulphate-base materials, **3006**
Panchenko, V. G., with S. B. Gurevich, ferroelectric materials, **1373**
Pancholy, M., with others, harmonic oscillations of quartz plates, **1619**
Panesenkov, F. F., magnetization of toroids with one and two air-gaps, **2584**
Pankove, J. I., and others, use of flying-spot scanner to study photo-sensitive surfaces, **890**
—— with others, Ge p-n-p-junction transistor, **876**
Pannenborg, A. E., scattering matrix of symmetrical waveguide junctions, **66**
Pantchechnikoff, J. I. See Pankove, J. I.
Panzer, S., h.f. h.v. equipment for electron microscope with intermediate accelerator, **2103**
Paolini, E., spontaneous voltage fluctuations in resonant circuit, **676**
Papas, C. H., and W. W. Salisbury, magneto-hydrodynamic waves in conducting liquids, **1661**
Parbrook, H. D., ultrasonic interferometer for high fluid pressure, **2542**
Parent, R. J., graphical analysis for circuits including overdriven valves, **356**
—— with R. J. Medkeff, diode-bridge limiter for analogue computers, **2367**
Parker, G. M., with R. W. Williams, source of continuously variable voltage for computer, **1056**
Parker, R., magnetoresistance of Al-Si-Fe alloys, **125**
Parkin, P. H., and W. A. Allen, acoustic design of auditoria, **3175**
—— and others, acoustics of Royal Festival Hall, **2198**
Parmenter, R. H., acousto-electric effect, **2281**
Parr, J. C., matching discontinuities in waveguides, **3477**
Parry, C. A., band-spreading for communication receivers, **812**
Parthasarathy, S., S. S. Chari and D. Srinivasan, dependence of sonic intensity at source on absorption coefficient in liquids, **2543**
—— M. Pancholy and A. F. Chhapgar, harmonic oscillations of quartz plates, **1619**
Partington, D. K., with J. C. West, phase-shifting pulse generator for thyratron control, **1629**
Parton, J. E., network analysis by repeated Voltage superposition, **655**
Parzen, P., space-charge-wave propagation in electron beam, **268, 3450**; effect of thermal-velocity spread on noise figure of travelling-wave valve, **3452**
—— with others, low-noise travelling-wave valve, **273, (C)2496**
Pask, J. A., with others, fundamentals of glass-to-metal bonding, **2712**
Patchett, G. N., television-waveform display apparatus, **2745**
Patmore, J., with others, digital to analogue converter, **148**
Patton, R. G., and P. Hatfield, ultrasonic applications in rubber industry, **493**
Paul, F. A., carbon-film resistor temperature coefficients, **1921**

World Radio History

Paul, W., and R. V. Jones, absorption spectra of PbS at various temperatures, **2020**
Pauli, R. T., with C. Mileikowsky, 1·5-MV accelerator for heavy particles, **508**
Pauling, L., theory of ferromagnetism, **3586**
Paulsen, E., serrasoid modulation, **1846**
Pauthenet, R., spontaneous magnetization of ferrites, **1397**
Pavel, E. A., and H. v. Schau, tests on star-quad broadcast-programme cable without loading coils, **1578**
Payne, D. V., distributed amplifier theory, **2612**
Payne, W. T., spinor theory of quadripole networks, **3226**
Peachey, F. A., R. Toombs and C. Gunn-Russell, B.B.C. monitoring technique for unattended transmitters, **548**
Pearce, A. F., and B. J. Mayo, Type-R5081 reflex klystron oscillator for f.m. at cm λ, **1214**
Pearcey, T., with M. Beard, electronic computer, **1050**
Pearson, G. L., and B. Sawyer, Si *p-n*-junction diodes, **905**
—— and M. Tanenbaum, magnetoresistance effect in InSb, **2896**
Pearson, M. D., with others, reflection of microwaves by metal-plate structures, **389**; compressional phase shifter for microwave measurements, **1440**
Pearson, R. M., and F. A. Benson, direct-reading thermistor bridge, **1749**, **(D)2740**, **(D)3366**
Peck, D. S., decade cold-cathode counter tube, **1867**
Peddle, E. A. R., applications of cold-cathode gas-discharge tubes in electronic switching, **288**
Pederson, C. N., A. A. Gerlach and R. E. Zenner, electronic function generator, **451**
Peelle, R. W., with K. G. Standing, improvement of resolution of scintillation counters, **2107**
Peifer, A. G., P. Parzen and J. H. Bryant, low-noise travelling-wave valve, **273**, **(C)2496**
Pell, E. M., Hall effect in BaO single crystals, **129**; recombination rate in Ge, **2892**
—— and R. L. Sproull, recording a.c.-Hall-effect apparatus, **1057**
Pelz, F. M., realizability conditions for series-parallel matrix of reactance quadripoles, **3225**; design of symmetrical bridge-type filters, **3235**
Penin, F., and G. Phélizon, distance-measuring equipment, **3315**
Pennell, E. S., vitreous silica for ultrasonic delay lines, **3637**
Penner, D. I., visual observation of radiation from waveguides, **1231**
Peoples, S. R., with others, reflection of microwaves by metal-plate structures, **389**; compressional phase shifter for microwave measurements, **1440**
Pepinsky, R., with B. C. Frazer, X-ray analysis of ferroelectric transition in KH_2PO_4, **2048**
Pepperhoff, W., electron emission from cold-worked metals, **1390**
Pepping, F., with M. Finck, radio communication on German railways, **210**
Percival, W. S., factors in design of wide-band television amplifiers, **1838**; solution of passive networks by mathematical 'trees', **2587**
Perers, O. F., B. K. E. Stjernberg and S. K. H. Forsgren, microwave propagation in optical range, **3097**
—— with S. K. H. Forsgren, recording of rain by radar, **2994**
Perets, V. B., with others, coercive force of nonuniformly magnetized specimens, **3024**
Peretz, R., measurement of effective values of welding currents, **194**
Pérez, J. P., and P. Johannin, piezoelectric resonance of quartz up to 5 000 atm, **442**
Perilhou, P., and J. Cayzac, stabilized h.v. rectifier unit for 5 kV, 50 mA, **2800**
Perlmutter, A., with others, induced conductivity of luminescent powders, **2021**
Pernik, J., recent developments in dry cells, **3727**
de la Perrelle, E. T., with F. L. Jones, field emission of electrons in discharges, **1982**
Perrier, A. L., transverse magnetogalvanic effects and resistivity, **1319**
Perron, R. R., contour recording by magnetic tape, **1449**
Perrot, M., and J. P. David, deviations from Ohm's law in thin metal layers, **2685**
—— with N. Nifontoff, resistance of imperfect contact between two metals, **3258**
Persoon, A. H., magnetic striping by laminating process, **2207**
Peter, M., with others, properties of very small ferroelectric particles, **3007**
Peter, R. W., low-noise travelling-wave amplifiers, **277**
—— J. A. Ruetz and A. B. Olson, attenuation of wire helices in dielectric supports, **1523**
—— with others, developments in travelling-wave valves, **1524**
Peters, J., significance of complex frequencies in communications technology, **657**; reduction of carrier-frequency build-up process to l.f. process, **1249**
—— with W. Händler, calculation of transients in carrier-current systems, **2246**
Peterson, A., and D. B. Sinclair, single-ended push-pull a.f. amplifier, **3250**
Peterson, A. M., with O. G. Villard, Jr, scatter sounding, a new ionospheric technique, **201**; extended-range communication in 15- and 20-m bands, **2421**
—— with others, double-Doppler investigation of meteor-trail echoes, **393**; transmission by reflection from meteoric ionization, **2117**
Peterson, D. W., with J. Epstein, field-strength surveys for u.h.f. television, **523**; experimental study of wave propagation at 850 Mc/s, **2423**
Peterson, H. A., with P. E. Russell, harmonic power generation with nonlinear reactor, **2455**
Petritz, R. L., theory of noise, in contacts, **79**, in *f-n* junctions and related devices, **871**
Petruzzelli, R. T., high-quality television unit for p.p.i. display, **2001**
Peuteman, A., precise determination of time interval, **1420**
Pfann, W. G., with others, observations of dislocations in Ge boundaries, **2693**
Pfister, W., magneto-ionic multiple splitting determined by phase-integration method, **2114**
Phélizon, G., with F. Penin, distance-measuring equipment, **3315**
Philipp, H. R., with I. L. Sparks, retarding-potential method for measuring conductivity of oxide-coated cathodes, **2835**
Phillips, A. H., and M. Cooperstein, modulation index of f.m. signals, **3071**
Phillips, E. T. A., with others, recent developments in phototelegraphy and facsimile transmission, **557**
Phillips, G. J., influence of ionosphere on m.f. broadcasting, **3096**
Phillips, W. E., automatically calibrated electronic frequency recorder, **2377**; high-speed telemetry system, **3674**
Picard, E., and A. Rogozinski, limitation of discharge propagation in G-M counters, **3390**
Piccardi, G., and R. Cini, potential in electrically shielded space, **1646**
Pick, H., with H. Mette, electronic conductivity of anthracene single crystals, **3016**
Pickens, D. H., analogue computer, **3043**
Piddington, J. H., thermal theories of high-intensity components of solar r.f. radiation, **1980**
Piefke, G., exponential transmission line and its radiation loss, **3187**
—— with others, h.f. equipment for 24-channel p.p.m. beam R/T system, **822**
Piepgras, E., square-wave generator, **2944**
Pierce, E. T., with F. Hepburn, atmospherics with very-low-frequency components, **2771**
Pierce, J. R., calculation of microwave noise in electron streams, **891**
Pierce, R. W., with W. P. Senett, stabilized power supply for electrometer valves, **1133**
Piercy, G. R., and E. R. Morgan, ferromagnetism and order in Ni-Mn alloys, **3025**
Pietermaat, F. P., and R. Antoine, h.f. tempering of band-saw teeth, **179**
Piggott, W. R., abnormalities in ionosphere at high latitudes, **1672**; reflection and absorption of radio waves in ionosphere, **1679**
—— with E. V. Appleton, ionospheric storms and geomagnetic anomaly in F_2 layer, **2308**
Pike, E. W., design of optimum filters, **2924**
Pikus, G. E., influence of electronic surface states on optical properties of semiconductors and dielectrics, **1304**
Pilod, P., with M. Laudet, potential distribution in e.s. electron lens, **3383**
Pimonow, L., ultrasonics in telephony, **1885**
Pincherle, L., with others, electronic band structure of PbS, **2037**
Pinet, A., experimental 12-channel p.c.m. system, **1125**
Pipes, L. A., mathematical analysis of dielectric amplifier, **70**; parallel-connected magnetic amplifiers, with resistive load, **(D)944**, with inductive load, **1251**; analysis of idealized series-connected magnetic amplifier, **3508**; matrix solution of Mathieu-Hill type equations, **3640**
Pippard, A. B., and R. G. Chambers, mean free path of conduction electrons in Bi, **996**
Pittman, G. F., Jr, with L. A. Finzi, comparison of methods of analysis of magnetic amplifiers, **2910**
—— with others, effective feedback ratio of magnetic amplifiers, **3510**
Plach, D. J., and P. B. Williams, horn-loaded loudspeakers, **314**
Plottin, G., with others, 3 signal generators covering range 20–1200 Mc/s, **1084**
Poeverlein, H., ionosphere critical frequencies for oblique incidence, **2115**
Poganski, S., blocking mechanism of Se rectifiers, **2699**
Pohlit, W., with W. Lippert, electron-optical properties of e.s. lenses, **795**
Poincelot, P., nonexistence of Sommerfeld's surface wave, **195**, **3686**; transient response of filters and transmission lines, **1248**; concept of instantaneous frequency, **2908**; extension of Fermat's principle to group propagation time, **3592**
PoKempner, M., with S. M. Ostrow, ionospheric critical frequencies and sunspot number, **1350**
Pokrovski, Ya. E., with S. G. Kalashnikov, influence of surface on type of conduction of semiconductor, **2686**
van der Pol, B., radio technology and theory of numbers, **3346**
Poleck, H., balance approach in a.c. bridges, **1434**
Polgreen, G. R., production and application of magnetic powders, **762**
Pollack, I., effect of frequency and amplitude distortion on speech intelligibility, **10**
Polovin, R. V., with A. I. Akhiezer, plasma oscillations in crossed electric and magnetic fields, **3591**
Ponthus, A., with G. Comte, measurements of attenuation of TE_{01} waves in circular waveguide, **1068**; determination of characteristic impedance of coaxial cables, **2732**
Pope, G. J., constant-volume amplifier, **365**, **(D)686**
Poritsky, H., electron-gas equations for electron flow in diodes, **1863**
—— and R. P. Jerrard, integrable case of electron motion in electric and magnetic field, **76**
Porter, J. H., speed-sensing relay, **499**
Porter, W. C., and W. E. Ramsey, circuit for limiting discharge in G-M counters, **73**
Portier, —, organization of civil aviation, **3419**
Portis, A. M., and others, electron-spin resonance in Si semiconductor, **3342**
Post, E. J., acoustic radiation pressure and dispersion, **1565**
Potter, J. L., with others, ratio meter measures reflection coefficient, **466**
Pottier, J., and A. Lavaitte, current and voltage regulators, **3725**
Pottinger, R. F. A., problems of sound in television programmes, **846**
Potts, J., with J. C. West, relation between closed-loop transient response and open-loop frequency response, **3231**
Poulis, N. J., and G. E. G. Hardeman, temperature dependence of spontaneous magnetization of antiferromagnetic single crystal, **3336**
Pourciau, L. L., television camera equipment, **2164**
Powell, F. H., with others, c.r. tubes and valves for television receivers, **1521**

World Radio History

Powell, R. C., simplified method for measuring attenuation of balanced transmission lines, **467**
Powell, R. M., radiation resistance of small horizontal loop aerial, **327**
Power, B. D., with others, working fluids for diffusion pumps, **1686**
Powers, R. L., with others, magnetic striping techniques, **2206**
Prabhu, K. S., with N. Narayan, production of standard waveforms with 3-MV impulse generator, **974**
Prache, P. M., a.c. resistance and reactance of round conductors, **1918**; primary parameters of uniform cable circuits, **2556**
—— and H. Billottet, magnetodynamics of ferrites, **1029**
Prache, P., with P. Tavernier, effect of pressure on resistance of thermistor, **342**
Pramanik, S. K., secular variation of geomagnetic field at Colaba and Alibag, **399**
Prast, G., Jr, with D. van Zoonen, properties of Ar-Br-filled counters, **1463**
Praxmarer, W., possibility of generating mm waves with pulsed rising-sun magnetron, **297**
Prechner, L. J., with T. W. Bennington, B.B.C. ionospheric-storm-warning system, **103**
Preist, D. H., C. E. Murdock and J. J. Woerner, high-power klystrons, **1213**
Presnov, V. A., relation between h.v. polarization of dielectrics and intensity of electric field, **2681**
Pressey, B. G., G. E. Ashwell and C. S. Fowler, measurement of phase velocity of 127·5-kc/s ground wave, **1782**
—— C. S. Fowler and R. W. Mason, precision phase comparator for l.f., **(A)483, 1080**
—— with others, ionospheric propagation of v.l.f., l.f. and m.f. waves, **1781**
Pressler, H., European broadcasting conference, Stockholm, 1952, **534**
Pressman, R., design of bistable multivibrators, **1946**
Preston, G. W., statistical equivalence of optimum transducers, **3700**
—— and J. C. Tellier, lock-in performance of a.f.c. circuit, **1280**
Preston, J., WJZ-TV emergency aerial system on Empire State Building, **631**
—— with others, uniaxial microphone, **2199**
Preston, J. G., measurement of television field strengths by helicopter, **576**
Price, R. E., travelling disturbances in ionosphere, **3294**
Price, T. W., with others, c.r. tubes and valves for television receivers, **1521**
Price, W. A., and E. H. Nelson, discharge lamps for television studios, **866**
Prichard, A. C., and M. Bernstein, impedance meters for crystal units, **2390**
Prim, R. C., field distribution in a 'swept intrinsic' semiconductor, **2689**
—— with W. Shockley, space-charge-limited emission in semiconductors, **3324**
Prime, H. A., Hg-vapour discharge, microwave admittance of, **1654**, absorption and reflection of microwaves by, **1656**
Prince, M. B., relation between pulse and charge-carrier drift mobilities in Ge, **3617**
—— with F. S. Goucher, current amplification factor for *p-n*-junction transistors, **2488**
Prins, J. A., J. Schenk and J. M. Dumoré, temperature distribution at end of hot wire, **283**
Pritchard, D. H., and R. N. Rhodes, colour-television-signal demodulators, **3436**
Pritchard, R. L., junction-type transistors, frequency variation of current gain for, **690**, collector-base impedance of, **(D)3212**
Pritsching, I., with K. Tamm, frequency analyser with mechanical filter, **1227**
Prowse, W. A., and P. E. Lane, u.h.f. breakdown of gas in crossed electric fields, **3261**
Prugne, —, and P. Garin, use of membranes in vacuum technique, **110**
Prugne, P., and P. Léger, uniform metallization of surfaces by thermal evaporation, **428**
Pryce, M. H. L., diffraction of radio waves by curvature of earth, **1776**
Przedpelski, A., with others, double-counter discriminator, **684**
Pugh, E. M., with S. Foner, Hall effect of Co-Ni alloys and armco iron, **3625**
Pungs, L., and G. Meinshausen, magnetic demodulation, **3400**
Purkis, H. J., with others, acoustics of Royal Festival Hall, **2198**
Püschel, B., voltage measurements on Rochelle salt under pressure, **735**
Putley, E. H., conductivity and Hall coefficient of sintered PbS, **120**; thermo- and galvano-magnetic coefficients for semiconductors, **1380**; intrinsic conduction in PbS, PbSe, PbTe, **1388**

Quiquandon, —, and — Lalmi, central telecommunications office for civil aviation, **3419**

Raabe, H. P., graphical spectrum analyser for pulse series, **3641**
Rabinow, J., notched-disk pulse-storage device, **494**
Raburn, L. E., f.m.-altimeter slot radiators, **2897**
"Radionyme", compressed television, **1824**
Rado, G. T., permeability tensor and Faraday effect in nonsaturated ferromagnetic materials, **1709**
—— and others, properties of ferrites at v.h.f., **1312**
Ragazzini, J. R., and L. A. Zadeh, analysis of sampled-data control systems, **(A)1801**
—— with L. A. Zadeh, optimum filters for detection of signals in noise, **205**
Rahman, A., accuracy of perturbation calculated from inaccurate unperturbed wave function, **3254**
Raithby, C. B., converter for 200 kc/s, **3698**
Rajchman, J. A., matrix digit-storage systems, **1728**
Ralston, R. W., and B. D. Wickline, television coverage of the 1952 National Political Conventions, **3134**
Ramberg, E. G., and L. Malter, potential distribution between accelerating grid and parallel anode, **1534**
Ramer, L. G., with others, reverberation-room measurements of loudspeaker efficiency, **2873**
Ramey, R. A., magnetic amplifier, single-core, as computer element, **3048**, mechanics of operation of, **3503**, control of, **3507**
Ramsay, J. F., with others, B.B.C. television transmitting aerials, **934**
Ramsey, W. E., with W. C. Porter, circuit for limiting discharge in G-M counters, **73**
Ranc, G., thin metal films, **430**
Rand, P. S., reduction of radiation from television receivers, **2476**
Randall, J. E., with H. M. Hines, possible dangers in industrial use of microwave radiation, **1093**
Rank, D. H., and D. C. Cronemeyer, infrared absorption of heat-treated Ge, **2678**
—— R. P. Ruth and K. L. Vander Sluis, determination of velocity of light by band-spectrum method, **987**
Rao, B. R., and K. S. Rao, measurement of ultrasonic velocities in liquids, **2859**
Rao, K. S., with B. R. Rao, measurement of ultrasonic velocities in liquids, **2859**
Raoult, G., and R. Fanguin, frequency-stabilized u.h.f. discriminator, **2386**
—— and R. Turlier, u.h.f. oscillations in triode valves, **2271**
Rappaport, W., with G. Boré, suitability of 'fixed level' recording method for propagation research, **2065**
Rasch, R., noise measurements on television transmissions, **868**
Raschkowitsch, A., spectral differences between a.m. and f.m. oscillations, **2484**; diode modulator for f.m., **2485**
Ratcliff, G., with J. B. Jenkins, automatic measurement of ionospheric absorption of vertical-incidence pulse signals, **1680**, **(D)3305**
Ratcliffe, J. A., with M. Ryle, radio astronomy, **92**
Ratcliffe, P. M., microwave-noise generators, **788**
Rathenau, G. W., J. Smit and A. L. Stuyts, ferromagnetic properties of ferroxdure materials, **751**
—— with others, preferred crystal orientation in ferromagnetic ceramics, **1036**
Ratner, L. T., with R. L. Murray, electric fields in cyclotron dees, **1765**
Ratz, A. G., and V. G. Smith, gating method for parallel computers, **2374**
Rau, K. H., with W. Hanle, light emission and destruction of phosphors by electron and ion impact, **734**
Rau, K. L., new thyratrons for telephone-circuit engineering, **3156**
von Rautenfeld, F., and H. W. Fastert, problems of u.s.w. coverage, **2139**
Rawer, K., calculation of sky-wave field strength, **199**; longitude effect in F region, **(D)2307**
—— with E. Harnischmacher, radio links covering very great distances, **520**
—— with others, effect of geomagnetic field on ionospheric absorption of short waves, **1678**
Raymond, F., electrical and mechanical analogies, **989**
Raymond, F. H., stability of multiple linear servo-system, **227**
Rayner, G. H., selective detector amplifier for 10 c/s–10 kc/s, **1633**
Raynor, G. V., band structure of metals, **2046**
Read, W. T., Jr, with W. Shockley, statistics of recombination of holes and electrons, **420**
Reboux, J., bibliography on h.f. induction heating, **3676**
Reche, K., progress in teleprinter technique, **2138**
Reddan, M. J., and G. F. Rouse, clean-up of He in arc discharge, **3604**
Reder, F., and E. Hafner, method of determining dielectric constants of fluids at cm λ, **1734**
Rediker, R. H., with others, phase-bistable transistor circuit, **3515**
Redington, R. W., diffusion of Ba in BaO, **432**
Reed, E. D., frequency-sweep method of *Q* measurement for single-ended resonators, **465**; coupled-resonator reflex klystron, **3160**
Reed, I. S., with others, phase-bistable transistor circuit, **3515**
Reed, J. R., with W. J. Renwick, silicone resins in insulation at power frequencies, **2352**
Reed, M., A. B. Atkinson and D. S. Clarke, factors affecting design of mass-production television receivers, **1496**
Reed, R., with others, conference on electron miscrocopy, Bristol, Sept. 1952, **1771**
Reed, R. H., modified magic-T phase shifter, **331**
Reeves, R. J. D., feedback-amplifier design, **983**
Reggia, F., u.h.f. magnetic attenuator, **1937**
—— and R. W. Beatty, u.h.f. magnetic attenuator, **964**
Rehman, I., E. Singer and C. S. Szegho, rotating-screen colour-television tube, **3740**
Reich, E., and P. Swerling, detection of sine wave in Gaussian noise, **2429**
Reich, H. J., admittance diagrams in oscillator analysis, **1944**
Reichardt, W., and I. Broser, effect of pounding on luminescence of ZnS phosphors, **2022**
Reichel, W., comparative survey of input stages of television receivers, **1167**
Reiches, S. L., with others, c.r. tubes with internal pole pieces, **257**
Reilley, E. M., R. S. Bender and H. J. Hausman, r.f. power supply, **1134**
Reina, F. Moyano. See Moyano Reina, F.
Reintjes, J. F., analogue electronic correlator, **453**
—— with M. J. Levin, 5-channel analogue correlator, **2366, 2720**
Reitan, D. K., with T. J. Higgins, capacitance calculation for circular annulus by subarea method, **2302**
Rekalova, G. I., optical and photoelectric properties of orpiment, **415**
Renaudin, D., brush-discharge ionization in dielectrics, **136**
Rendall, A. R. A., and W. N. Anderson, temporary links for television outside broadcasting, **1143**
—— and G. A. Hunt, transmitter combining circuits, **870**
—— with others, test equipment for television transmission circuits, **1823**
Renwick, W. J., and J. R. Reed, silicone resins in insulation at power frequencies, **2352**
Resegotti, L., inductive waveguide attenuator, **2599**
Reule, A., emission from solar corona at λ 10 cm–10 m, **3277**

World Radio History

Reuterswärd, C., two-directional focusing with short uniform magnetic fields, 175
Reynolds, D. C., with others, single synthetic CdS crystals, 135
Reynolds, F. W., and G. R. Stilwell, mean free paths of electrons in evaporated Cu and Ag films, 714
Reynolds, J. H., isotopic constitution of Si, Ge and Hf, 3341
Reynolds, L. G., errors of Decca navigator system used over land, 1025
Reza, F., theorems on 2-terminal networks, 3532
Rezanov, A. I., thermal and thermoelectric properties of ferromagnetic metals, 1394
Rhodes, D. R., optimum linear array for single main beam, 2571
Rhodes, R. N., with D. H. Pritchard, colour-television-signal demodulators, 3436
Riblet, H. J., synthesis of narrow-band direct-coupled filters, 58, (D)3234
Rice, P. L., W. V. Mansfield and J. W. Herbstreit, ground-to-air cochannel interference at 2·9 kMc/s, 1798
Rice, S. O., statistics of field-strength fluctuations far beyond horizon, 1473
Richards, M. S., equipment for observation of very-high-speed phenomena, 1763
Richardson, E. G., acoustics in relation to radio engineering, 911
Richardson, H. K., 1952 Audio Fair, 1218
Richardson, W. D., Northern England television outside broadcasts, 560
Richman, D., frame synchronization for colour television, 236
Rideout, V. C., with H. Chang, generalization of modulation spectra, 2790
Rider, G. C., v.h.f. experiments on diffraction effects of hills, 3091
Ridout, M. S., potential-barrier height in barrier-layer cells, 1852
Rieke, J. W., and R. S. Graham, television terminals for L3 coaxial-cable system, 3424
Rieth, H. F., compact u.h.f. television tuner, 571
Riéty, P., electronic antiresonant circuit, 2591
Righini, G., and G. Godoli, solar influence in gyro-interaction experiments, 3693
Rimai, E., with F. Assadourian, theory of microstrip transmission lines, 622, 2213
Ringer, K., with others, double-counter discriminator, 684
Ritchie, E. J., addition agents for negative plates of Pb-acid storage batteries, 2157
Ritson, F. J. U., and P. H. Hammond, electronic simulator for hydraulic servomechanism, 1054
Rittenhouse, J. W., cathode-drift compensation in d.c. amplifiers, (A)2617
Ritterman, M. B., autocorrelation theory and television video signal, 3121, 3122
Rivkin, S. M. See Ryvkin, S. M.
Robbins, H., with others, magnetic striping techniques, 2206
Robeer, A. G., 100-kW s.w. broadcasting transmitter, 2819
Roberson, R. E., iterative method for nonlinear vibrations, 3571
Roberts, A., Jr, with others, magnetic striping techniques, 2206
Roberts, E. A., and P. Goldsmith, piezoelectric crystals for pressure, temperature and humidity measurements, 2403
Roberts, F., and J. Z. Young, flying-spot microscope, 1759
—— J. Z. Young and D. Causley, flying-spot microscope, 3073
Roberts, F. F., with others, structure and properties of ferrites, 2043
Roberts, N. F., and L. T. Wilson, counting pulses of various forms and occurrence intervals, 1257
Roberts, S., electroluminescent powders in dielectric media, 3575, 3576
Roberts, T. E., Jr, theory of single-wire transmission line, 1580
Roberts, V., and A. S. Young, PbSe photoconductive cells in infrared spectroscopy, 3142
—— with D. A. H. Brown, high-speed infrared spectrometer, 1758
Roberts, W. van B., ferrite magnetostrictive resonators, 2229
Robin, L., autocorrelation function and power-density spectrum of clipped thermal noise, 532; calculation of harmonic distortion in f.m. or ph.m., 1282; optimum clipping for pulse signal with superposed thermal noise, 2781
Robinson, A. A., multiplication in Manchester University computer, 1051
Robinson, H. L., diffraction patterns in circular apertures of diameter $< \lambda$, 1666
Robinson, N. P., with I. C. Browne, cross-polarization of radar melting-band, 1364
Robinson, T. S., transformers for infrared chopped-beam systems, 942
Roch, R., and J. A. Ville, transmission parameters of a cable amplification section, 2559
Roche, A. H., and L. E. Weaver, television frequency-translating terminal equipment for the Birmingham/Holme-Moss coaxial cable, 1149
Rochelle, R. W., c.r-tube beam intensifier, 162
Rockett F. H., Jr, with E. G. Fubini, bandwidth of $\lambda/4$ sections, 30
Rockstuhl, F. G. R., analysis of fundamental and harmonic crystal-oscillator circuits, 358
Rodenhuis, K., with others, decade tube for high counting rates, 3762
Rodina, E. A., with others, single-electrode discharge at 31·7 Mc/s, 1307
Rodnikova, I. V., with V. M. Kel'man, motion of charged particles in e.m. field of linear current and e.s. field of cylindrical capacitor, 75
Roessler, E., special type of p.m. for transmission of radar pictures, 'Durchmusterung', 2002
Rogers, A. W., and B. A. Diebold, components and materials for reliable electronic equipment, 2261
Rogers, D. C., travelling-wave valve as output amplifier in cm-λ radio links, 2829
—— and P. F. C. Burke, British television relay uses travelling-wave valves, 2830
Rogers, T. H., rectifier valve for extremely high power and voltage levels, 2155
Rogozinski, A., with E. Picard, limitation of discharge propagation in G-M counters, 3390
Rohan, P., use of short transmission lines in u.h.f. techniques, 2917
Rohmer, R., with others, lattice defects and Debye r.f. absorption in iron oxides, 2328, (C)3612
Roka, E. G., C. H. Jackson and R. P. Ulrich, evaporated-point-contact rectifiers, 2179
Rollin, B. V., and E. L. Simmons, infrared photoconductivity of Si at low temperatures, 2014
—— and I. M. Templeton, noise in semiconductors at v.l.f., 2039
Romand, J., R. Aumont and B. Vodar, variation of resistance of thin metal films as function of applied potential, 3339
—— with R. Aumont, precision measurement of direct voltages by comparison, 2726
Romanowski, M., bridge method for absolute determination of ohm, 1426
Ronchi, L., and G. Toraldo di Francia, determination of reflection coefficient of stratified medium by calculus of variations, 1314
Rooksby, H. P., with B. T. M. Willis, crystal structure and antiferromagnetism in haematite, 1311
Roos, W., auxiliary circuits in studio, 223
van Roosbroeck, W., large current amplifications in filamentary transistors, 1516; transport of added current carriers in homogeneous semiconductor, 3611
Roques, P., adaptation of French television receivers to American standards, 2471
Rorden, H. L., and R. S. Gens, radio noise in relation to design of h.v. transmission lines, 927
Rose, D. J., and S. C. Brown, admittance and electron density of h.f. gas discharge, 463
Rose, G. M., and B. N. Slade, transistors operate at 300 Mc/s, 585
Rosen, J., with others, evaporation of Ge films from carbon crucible, 3032
Rosenthal, J. E., with A. Bramley, field-dependent luminescence of vitreous Zn_2SiO_4 phosphor, 418
Rosenthal, L., resistive bidirectional coupler, 2592
Rosenthal, L A., J. L. Potter and G. M. Badoyannis, ratio meter measures reflection coefficient, 466
Ross, G. I., with L. E. Tagholm, selection and testing of sites for television transmitters in United Kingdom, 1172
Ross, H. A., design of single-phase transductors, 1254
Ross, I. M., with G. C. Dacey, unipolar field-effect transistor, 3445
Rossetti, C., interferometer measurements on ultrasonic waves, 1223
Rostoker, N., interpretation of experiment on metals with positive Hall coefficient, 1300
Roth, L., and W. E. Taylor, preparation of Ge single crystals, 744, (C)1408
Rothe, H., limiting sensitivity of triode amplifying valves, 1203; circuit and valves for u.s.w. receivers, 2428
—— and E. Willwacher, limiting sensitivity of amplifier valves, 1538
—— W. Dahlke and J. Schubert, measurement of flicker-effect constants, 2725
Rothen, F., Swiss radio communication and broadcasting organizations, 1123
Rottgardt, K. H. J., luminescence decrease due to electron irradiation, 3322
Rouault, C. L., and G. N. Hall, h.v. medium-power p-n-junction rectifier, 835
Roubine, É., guiding of e.m. waves by helices, 388
Round, H. J., magnetostriction transducer measurements, 5
Rouse, G. F., with M. J. Reddan, clean-up of He in arc discharge, 3604
Rousseau, J., radio components exhibition, Paris, 1953, 2262
Roux, J., photodielectric effect, ferroelectricity and thermoluminescence of ZnO under u.v. irradiation, 3005
Rowe, E. G., technique of reliable valves, 272
Rowe, H. E., noise analysis of a single-velocity electron gun, 1848
Rowlands, R. O., harmonic distortion and negative feedback, 2278, (D)3253, (D)3568
Roy, R., with B. M Banerjee, high-precision ionosphere-sounding equipment, 1677
Roys, H. E., distortion in phonograph reproduction, 2736
Rubinoff, M., design of Eccles-Jordan flip-flops, 952
—— with C. Leondes, DINA, digital analyser for Laplace, Poisson, diffusion and wave equations, 3045
Ruch, E., with R. Müller, e.m. self-oscillations in rectangular cavity with finite wall conductivity, 67
Rudd, J. B., 'codan' noise eliminator for a.m. receivers, 2132; reciprocal ladder networks, 2589
Rudenberg, H. G., with R. C. Hergenrother, direct-reading oscilloscope for 100-kV pulses, 3067
Rudnick, P., detection of weak signals by correlation methods, 2124
—— with V. C. Anderson, thermistor-bridge correlator, 3350
Rueger, L. J., and R. J. Nuckolls, Stark cell for microwave spectroscopy, 1317
—— and A. E. Wilson, N.B.S. microwave standard-frequency service, 2063
—— with others, microwave absorption spectrum of ND_3, 2298
Ruetz, J. A., with others, attenuation of wire helices in dielectric supports, 1523
Rukop, H., equations for natural frequencies of coupled circuits from quadripole viewpoint, 1276
Rumer, Yu. B., theory of conductivity of metals in magnetic field, 378
Runge, W. T., distortion in anode-modulated transmitters, 262
Rupprecht, G., with G. Heiland, logarithmic-scale valve galvanometer, 3363
Russell, D. W., and C. H. Weaver, synthesis of servomechanism by root locations, (A)2150
Russell, P. E., and H. A. Peterson, harmonic power generation with nonlinear reactor, 2455
Rust, H. H., and E. Bailitis, ultrasonic-wave generators using dumb-bell type magnetostrictive oscillators, 1556
—— with others, variation of partial processes in magnetostriction, 130
Rust, W. M., Jr, field test of split-channel 50-Mc/s systems, 3709
Rutelli, G., aerials of modern high-power television stations, 632
Ruth, R. P., with others, determination of velocity of light by band-spectrum method, 987

World Radio History

Rutishauser, H., automatic programme planning for computers, **147**
Ryan, W. E., with R. C. Ellenwood, u.h.f. matching termination, **1073**
Ryazonova, T. P., with V. I. Kalinin, theory of multisegment magnetron, **3458**
Ryder, E. J., mobility of holes and electrons in high electric fields, **3326**
Ryder, J. D., and M. S. McVay, thermocouple a.f. wattmeter, **2394**
Ryle, M., and J. A. Ratcliffe, radio astronomy, **92**
—— with P. A. G. Scheuer, radio investigation of H II regions, **3278**
Rytov, S. M., electron deflection by charged filament, **1299**
—— with M. A. Leontovich, differential law of electrical fluctuations and influence of skin effect, **2951**
Ryvkin, S. M., choice between 'barrier layer' and 'concentration' theories of photoconductivity, **3605**
—— and L. N. Malakhov, effect of oxygen on PbS photoresistors, **3040**

van Sabben, D., solar-flare effects and magnetic storms, **3276**; relation between radio-propagation disturbance, geomagnetic activity, and solar noise, **3283**
Saby, J. S., fused-impurity Ge *p-n-p*-junction transistor, **877**
—— and W. C. Dunlap, Jr, impurity diffusion and space-charge layers in fused-impurity semiconductors, **3020**
Sacasa, R. Gea. See Gea Sacasa, R.
Sacco, L., graphs for u.s.w. propagation, **2118**
Sacerdote, G. G., with M. Ferrero, measurement of acoustic impedance, **2545**
Sack, R. A., and J. J. O'Dwyer, frequency dependence of dielectric properties of dipolar substances, **1647**
Sackmann, L. A., representation of experimental results by equations, **370, 371**
Sagajllo, W., problems in a.f. spectrum analysis, **(D)776**
Saha, A. K., with S. S. Baral, observations at Calcutta of pulses transmitted from Delhi, **2116**
de Saint-André, R., applications of Type-ECH42 triode-hexode, **590**
Sakata, T., conductivity and thermo e.m.f. of Cs_3Sb photocathodes, **3002**
Saker, E. W., temperature variation of rectification characteristics at Se contacts, **1389**
Sakiotis, N. G., and H. N. Chait, ferrites at microwave λ, **931**
—— with others, reduction of loss in ferrite gyrators, **1610**
Sakurai, T., theory of convex-waveguide lens, **3204**
Salam, S. A., with R. Mansfield, electrical properties of molybdenite, **2708**
Salisbury, W. W., with C. H. Papas, magneto-hydrodynamic waves in conducting liquids, **1661**
Salmon, D. P., with W. Bacon, *RC* circuits with voltage gain, **663**
Salomonovich, A. E., automodulation in ferroresonant circuits, **1270**
Salort, P., with P. Chavance, thick obstacles in waveguides, **3190**
Salpeter, J. L., developments in sintered magnetic materials, **3334**
Saltzer, C., second fundamental theorem of networks, **2585**
Salz, N. P., with others, Ge diode as video detector, **2475**
Salzer, J. M., characteristics of digital- and analogue-computer units, **2363**
—— with W. K. Linvill, analysis of control systems involving digital computers, **3075**
Samoilovich, A. G., and V. A. Yakovlev, additional resistance of ferromagnetic metals, **1402**
Sampson, H. O., television lighting technique, **865**
Sánchez Cordovés, J., illumination in television studios, **1164**; television amplifiers, **3744**
Sander, K. F., and J. G. Yates, accurate mapping of e.s. fields in electrolyte tank, **2739**
Sands, E. A., properties of magnetic materials under current-pulse conditions, **128**; analysis of magnetic-shift digit-storage operation, **3352**
Sann, K., with H. Awender, activity measurement for quartz crystals in parallel-resonance circuits, **1273**
van Santen, J. H., with Y. Haven, pre-exponential factors in formulae for ionic conductivity in solids, **3578**
—— with G. H. Jonker, ferromagnetic compounds of Co with perovskite structure, **2701**
Saporte, R., with C. Fert, electron microscopy by reflection, **1457**
Saraga, W., graphical methods for analysis and design, **(D)349**; filters with minimum number of inductors or capacitors, **2595**
—— D. T. Hadley and F. Moss, aerial-radiation-pattern analogue computer, **3198**
Sarazin, A., standing-wave linear accelerator for 1·2-MeV electrons, **3078**
Sarginson, K., with D. K. C. MacDonald, galvanomagnetic effects in conductors, **1974**
Sarser, D., and M. C. Sprinkle, 'Maestro' a.f. power amplifier, **978**
Sarzhevski, P. E., variation of conductivity of quartz, **1378**
Sasaki, T., with others, dielectric constant of Rochelle salt at 3 kMc/s, **2729**
Sato, R., with others, *h't* ionosphere measurements at Wakkanai, Japan, during eclipse of 9th May 1948, **2659**
Saunders, E. A., and G. R. Cooper, meter for coupling coefficient of i.f. transformers, **3658**
Savant, C. J., with others, linear-to-logarithmic voltage converter, **3042**
Savant, C. J., Jr, design curves for notch networks, **2255**
Savornin, F., with J. Savornin, thermoelectric power of *p*-type Si, **82, 2335**
Savornin, J., and F. Savornin, thermoelectric power of *p*-type Si, **82, 2335**
Saw, P. D., design of large-screen receiver, **2811**
Sawyer, B., with G. L. Pearson, Si *p-n*-junction diodes, **905**
Saxton, J. A., v.h.f. long-distance propagation in relation to television in United Kingdom, **1110**; Scientific Instrument Manufacturers' Association exhibition, London, 1952, **1547**
—— with J. A. Lane, dielectric dispersion in electrolytes at u.h.f., **698**
Scanlon, W. W., with others, capacitance effects in thin conductive films, **2682**
Scarfe, E. C. R., continuous measurement of cable diameter, **791**
Schachenmeier, R., and F. Weller, refractive index of dipolar gas mixtures at dm λ, **1642**
Schaetti, N., and W. Baumgartner, dark current of electron-multiplier photocells, **1518, 2492**
—— with W. Baumgartner, infrared-sensitive electron-multiplier photocell, **1520**
—— with E. Keonjian, experimental investigation of transistor noise, **887**; noise in transistor amplifiers, **1288, 2279**
Scharf, A., with C. D. Miller, isotransport camera for 100 000 frames/sec, **2056**
Scharowsky, E., properties of ZnO single crystals with excess Zn, **3628**
v. Schau, H., with E. A. Pavel, tests on star-quad broadcast-programme cable without loading coils, **1578**
Schelisch, E. F., laboratory power meter, **786**
Schelkunoff, S. A., Advanced Antenna Theory, **(B)940**
—— and H. T. Friis, Antennas, Theory and Practice, **(B)637**
Schenk, J., with others, temperature distribution at end of hot wire, **283**
Scherrer, P., with others, anisotropy of dielectric constant of ice, **2027**
Scheuble, W., sorption properties of thin Ni films, **3271**
Scheuch, D. R., with O. Whitby, output analysis and alignment techniques for phase-rotation s.s.b. transmitters, **2481**
Scheuer, P. A. G., and M. Ryle, radio investigation of H II regions, **3278**
Schiesser, H., and O. Schmidbauer, standardization of magnetic-recording technique, **22**
Schiffman, T., with H. Ekstein, response of linear network to frequency-sweep input, **664**
Schilling, H., with H. Müser, thermoelectric measurements on Cu_2O, **3613**
Schimpf, L. G., with others, junction-transistor tetrode for h.f., **677, 1184**
Schiske, P., e.s. single lens permitting rigorous calculation, **2095**
Schlaak, N. F., s.s.b. system for overseas telephony, **541**
Schlesinger, K., transfer characteristics and mu factor of picture tubes, **2171**
Schlicke, H. M., quasi-degenerate modes in high-permittivity-dielectric resonators, **1942**
Schliebs, G., basic features of programme for chess-playing computer, **3046**
Schlüter, A., plasma, dynamics of, **1309**, in magnetic field, **1964**, relation between various types of oscillation in, **1965**
Schmid, A. E., 60-c/s magnetic amplifier in position-indicating servo-mechanism, **335**
—— with others, improved magnetic servo amplifier, **(A)3724**
Schmidbauer, O., field of magnetic-recording tape with ideal and with wide-gap pickup head, **1575**
—— with H. Schiesser, standardization of magnetic-recording technique, **22**
Schmidt, E., commercial experiences with 'magna stripe', **2205**; new magnetic-recording tape, **2553**
—— and E. W. Franck, manufacture of magnetic-recording materials, **2204**
Schmidt, H., measurements on $BaTiO_3$, **1694**
Schmidt, H. M., measurement of frequency of f.m. transmitter, **3660**
Schmidt, K. O., directional-radio equipment and planning of directional links in Western Germany, **2140**
Schmidt, P. S., developments in fixed capacitors, **953**
Schmidt, W., dynamic characteristics of magnetic amplifiers, **2579**
Schneider, F., low running potential of h.f. discharge between plane plates, **703**
Schneider, H., investigation of fine structure of valve characteristics, **3143**
Schneider, O., statistical treatment of geomagnetic micropulsations, **2643**
Schnell, L., measurement of dielectric loss angle, **781**
Schnitger, H., and D. Weber, travelling-wave valve, experimental verification of theory of, **280**, for 15-cm λ, measurements on, **2499**, reduction of noise factor in, **3754**
Schoch, A., concept of acoustic energy, **2860**; momentum of sound wave, **3165**
—— and K. Fehér, investigation of sound transmission through partitions, using models, **609**
Schodder, G. R., F. K. Schröder and R. Thiele, improvement of audibility in a theatre, **1572**
Scholes, D. H. C., radio in navigation and operation of civil aircraft, **1024**
Scholes, W. E., with others, acoustics of Royal Festival Hall, **2198**
Scholte, J. W. A., and W. C. van Geel, impedances of electrolytic rectifier, **2801**
Scholz, A., and G. Stuwe, frequency markers and scales for visible-indication instruments, **1077**
Scholz, W., u.s.w. links for television programme exchange with Berlin, **1810**
Schooley, A. H., simple computer automatically plots correlation functions, **3047**
—— and S. F. George, signal/noise characteristics of detectors, **529**
Schouten, G. H., a.g.c. by means of NTC resistors with heating element, **1953**
Schouten, J. F., F. de Jager and J. A. Greefkes, delta modulation, **543**
Schrag, R. L., with J. J. Gibbons, solving wave equation for region of rapidly varying refractive index, **803**
—— with others, long-delay ionospheric echoes at 150 kc/s, **1992**
Schröder, F. K., sound absorption as function of angle of incidence, **2548**
—— with others, improvement of audibility in a theatre, **1572**
Schroeder, A. C., with R. D. Kell, optimum utilization of r.f. channel for colour television, **3431**
Schröter, F., storage and picture-difference methods in television reception, **2163**
Schubart, G., with others, dependence of low-temperature conductivity of Cu_2O on oxygen pressure, **1385**
Schubert, J., with others, measurement of flicker-effect constants, **2725**
Schuder, J. C., with J. M. Cage, gas-tube inverter for low direct voltages, **2456**
Schultz, G. F., Russian *C*- and *R*-value notations, **2927**
Schulz, E., G. Piefke and E. Seibt, h.f. equipment for 24-channel p.p.m. beam R/T system, **822**
Schulz, G., with P. Kunze, l.v. counter tubes, **3085**
Schulze, A., and H. Eicke, Au-Cr standard resistors, **772**

World Radio History

Schumann, W. O., propagation of waves in inhomogeneous plasmas, **712**; propagation of very long e.m. waves, and wave spectrum of lightning, **802**, **1772**; natural oscillations of conducting sphere surrounded by air and ionosphere layers, **3596**, **3597**
Schunemann, C. F., with J. R. Martin, measurement of λ in mm, **2384**
Schurr, K., stabilization of variable-carrier-frequency servomechanisms, **551**
Schuster, K., with R. Meier, sound-wave propagation in piezoelectric crystals, **3014**
Schwabe, E., effect of small ellipsoidal inclosures on ferromagnetic coercive force, **3026**
Schwan, H. P., and K. Sittel, Wheatstone bridge for admittance determinations, **(A)3367**
Schwantes, R. C., with others, aircraft radio-interference measurements, **2075**
Schwarcz, L., with others, synchrocyclotron for 450-MeV protons, **1764**
Schwartz, E., television projection-type receivers, **251**; television projection installations, **1168**, **(C)2170**, **2472**
—— with W. Nestel, principles for planning of u.s.w. broadcasting systems, **2789**
Schwartz, L. S., second-detector signal/noise improvement, **527**
Schwarz, H., ionization method for high vacua, **2011**, **3320**; photosensitivity of self-quenching G-M counters with external cathode, **3088**
Schweiger, R. N., d.c. μA integrator, **1745**
Schweitzer, H., efficiency of small mains supply units with capacitively terminated rectifiers, **2799**
Schwenkhagen, H. F., Laplace transformation, **3041**
Schwetzoff, V., development of Cs-AgO photocathode during heat treatment, **3447**
Sciama, D. W., with others, electronic band structure of PbS, **2037**
Scott, A. H., measurement of multimegohm resistors, **3056**
Scott, D. R., and R. F. Hudson, analogue computer for mine-ventilation networks, **3349**
Scott, H. H., intermodulation measurements, **2737**
Scott, J. C. W., solar effect on E and F_1 layers at high latitudes, **406**
Scott, N. R., amplitude stability in oscillating systems, **3242**
Scott, R. E., S. Fine and A. Macmullen, nonlinear filtering and wave-shape multiplexing, **670**
Scovil, G. W., Hall effect in Ti, **2049**
Seaman, M. S., with F. A. Benson, phase-angle measurements with c.r.o., **1739**
Seeger, K., electron emission from metals after irradiation, **3266**
Seeliger, R., adjustment of spherically corrected electron-optical systems, **2100**
Seemann, E., assessment of transient distortion of loudspeakers, **17**
Segrave, P. A., with others, design of superheterodyne receiver for television, **1504**
Segrott, W. H., design for communications receiver, **3697**
Seguin, P., with others, preparation and properties of arsenide semiconductors, **3325**
Seibt, E., with others, h.f. equipment for 24-channel p.p.m. beam R/T system, **822**
Seiden, J., cosmotron, elimination of effects of faulty alignment in, **2405**, effect of magnetic defects in, **2753**
Seiffert, K. W., oscillograph representation of degree of distortion in teleprinter signals, **3408**
Seiler, K., and others, thermally produced lattice defects in Ge, **1697**
—— with D. Geist, temperature dependence of backward current in Ge p-n junctions, **423**
—— with others, plastic deformability of Ge, **2033**
Seitz, F., plasticity of Si and Ge, **1404**
Selis, O. J., radio navigation and air traffic safety measures, **2010**
Semmelink, A., e.m. testing of winding ropes, **3378**
—— with J. P. A. Lochner, electroacoustics laboratory at School for the Deaf, Worcester, C.P., **3**
Sempers, C. A., with G. W. Bridger, compact radar test unit, **1445**
Sen, H. K., solar 'enhanced radiation' and plasma oscillations, **1322**; estimate of density and velocity of solar material from data on r.f. outbursts, **1982**
Sen, S. K., and B. M. Bhattacharyya, triggering of plate-coupled multivibrator by negative pulses, **3557**
Senett, W. P., and R. W. Pierce, stabilized power supply for electrometer valves, **1133**
Senior, T. B. A., diffraction of dipole field by half-plane, **2296**
Septier, A., e.s. immersion objective, new type of, **186**, resolving power of, **187**, with thick electrodes, potential distribution on axis of, **1102**, with plane electrodes, **1458**, **1770**; obtaining electron images of surfaces bombarded by ions, **3388**
Seraphin, B., with J. Fassbender, growth and decay of photoconductivity of CdS single crystals, **1688**
Serny, J., stabilizer for high direct voltages, **838**
Setchfield, J. B., with others, microwave techniques for communication links, **219**
Severin, H., Kirchhoff's theory in calculation of cm-wave diffraction effects, **1296**
—— and C. Starke, diffraction of sound waves by circular apertures, **1557**
Seymour, E. F., with W. S. Carley, high-characteristic-impedance delay lines, **2257**
Sharma, J., with H. N. Bose, decay of long-period afterglow of alkali halides after c.r. excitation, **2680**
Sharp, C. E., and G. Goubau, u.h.f. surface-wave transmission line, **930**
—— with R. E. Lacy, f.m. microwave radio relay equipment, **1127**
Sharpe, J., with P. Holton, corona-stabilized h.v. supply for proportional counters, **1803**
Shaw, E. A. G., attenuation of higher modes of acoustic waves in rectangular tube, **2537**
Shea, R. F., stabilization of transistor operation, **688**, **(C)3248**
Shearman, E. D. R., with C. Clarke, automatic ionospheric-height recorder, **3356**
Sheingold, L. S., susceptance of circular obstacle in round waveguide with TE_{01} wave, **2565**
—— with others, graphical analysis of two-port waveguide junction, **3191**
Shekel, J., matrix representation of transistor circuits, **642**; sketch of algebra of switchable networks, **2913**; gyrator as 3-terminal element, **3228**
Shellard, H. G., with others, humidity of upper troposphere and lower stratosphere over southern England, **1671**
Shelton, E. E., and F. Wade, corona discharge tubes for voltage stabilization, **1136**, **(D)2803**
Shen, D. W. C., synthesis of uniform transmission line, **2880**
Shephard, N. H., channel-splitting demonstrations in Syracuse, **3707**
Shepherd, A. A., poisoning of oxide-cathode emission by oxygen, **1190**, **2503**
Shestopalov, V. P., waveguide containing spiral, partly filled with dielectric, **2884**
Shimizu, T., with others, *h't* ionosphere measurements at Wakkanai, Japan, during eclipse of 9th May 1948, **2659**
Shimoda, K., coherence of microwaves generated by klystron, **2943**
Shinn, D. H., with T. C. Cheston, scanning aberrations of radar lenses, **731**
Shipley, D. W., spherical aberration of e.s. electron lens, calculation of, **1100**, measurement of, **1459**
Shipley, F. M., with V. A. Johnson, adiabatic Hall effect in semiconductors, **3018**
—— with others, low-temperature Hall curve for n-type Ge, **426**
Shirane, G., and A. Takeda, transition energy and volume change in $BaTiO_3$, **2053**
Shive, J. N., properties of Type M-1740 p-n-junction photocell, **889**; properties of Ge phototransistors, **2825**
—— with others, optical encoder and digit register using transistors, **766**, **2373**
Shockley, W., transistor physics and analogue transistors, **746**; unipolar field-effect transistor, **879**; interpretation of e/m values for crystals, **1301**; cyclotron resonances, magnetoresistance and Brillouin zones in semiconductors, **3017**
—— and R. C. Prim, space-charge-limited emission in semiconductors, **3324**
—— and W. T. Read, Jr, statistics of recombination of holes and electrons, **420**
—— with T. S. Benedict, microwave determination of collision frequency of electrons in Ge, **2330**
Shortley, G., Tchebycheff-polynomial operators in numerical solution of boundary-value problems, **2713**
Shul'man, A. R., and V. L. Makedonski, secondary emission from dielectrics under single-pulse conditions, **3008**
Shul'man, M. S., with others, composition and properties of $BaTiO_3$ ceramics in strong fields, **3010**
Shulman, R. G., and D. M. Van Winkle, pressure-welded Ge p-n junctions, **2034**
Sichak, W., with others, high-gain loop aerial for television broadcasting, **1236**
Siebertz, K., new-type discharges in magnetic fields, **1652**
Siedentopf, H., and A. Behr, ionosphere disturbance of 23rd–28th Feb. 1952, **101**
Siegman, A. E., with D. A. Watkins, helix impedance measurements using electron beam, **3753**
Sieminski, E., field plotting in deflection-yoke design, **256**
Sigeharu Yamada. See Yamada, Sigeharu.
Silberg, P. A., with others, positive and negative ions in c.r. tubes, **2846**
Silberstein, J. M., test-pattern generator for production testing of television receivers, **2746**
Silberstein, R., with W. L. Hartsfield, comparison of c.w. field intensity and back-scatter delay, **808**
Silleni, S., intelligibility recorder for radiotelegraphy signals, **3696**
Sim, A. C., calculation of energy flow by means of Laplace transform, **955**; design of series peaking transformers, **1598**; h.f. proximity-effect formula, **2918**
Simmons, A. J., compact wide-band microwave $\lambda/4$ plate, **(C)2215**
Simmons, E. L., with B. V. Rollin, infrared photoconductivity of Si at low temperatures, **2014**
Simms, A. G., frequency spectrum of locked oscillator, **2605**
Simon, H., acoustic problems at Waldbühne open-air theatre, Berlin, **1573**
—— with others, aerial systems for 24-channel p.p.m. beam R/T system, **822**
Simon, J. C., and G. Broussaud, u.h.f. band-pass filters, **1933**
—— and G. Weill, longitudinal radiation of dielectric aerials, **1244**
Simon, R. F., with others, instrumentation for geophysical exploration, **2749**
Simon, S., cold-cathode tubes in switching systems, **538**
Simpkin, K. H., a.c. and d.c. as signal source in analogue computers, **2717**
Simpson, J. A., with others, electron-beam interferometer, **3074**
Simpson, J. H., and H. L. Armstrong, reverse characteristics of Ge rectifiers, **1715**
Simpson, L. C., Israel intercity R/T systems, **2442**
Simpson, P. A., with L. T. Sogn, loading of quartz oscillator plates, **966**
Sims, G. D., with P. A. Lindsay, application of thermodynamics of irreversible processes to magnetron theory, **2847**
Sinclair, D. B., with A. Peterson, single-ended push-pull a.f. amplifier, **3250**
Sinegubova, L. S., with others, effect of polarizing field on dielectric properties of $BaTiO_3$, **112**
Singakov, E. V., and B. K. Chernyi, potential distribution in titanate ceramic dielectrics, **439**
Singer, E., with others, rotating-screen colour-television tube, **3740**
Singer, S. F., E. Maple and W. A. Bowen, Jr, 'dynamo' currents and conductivities in ionosphere, **1353**
Sinno, K., F_2-layer variations accompanying geomagnetic storms, **3303**

World Radio History

Sinyakov, E. V., E. A. Stafiychuk and L. S. Sinegubova, effect of polarizing field on dielectric properties of $BaTiO_3$, **112**
Sisson, E. D., *RC* networks in amplifier design, **2593**
Sittel, K., and E. Menzer, improved radiosonde, **497**
—— with H. P. Schwan, Wheatstone bridge for admittance determinations, **(A)3367**
Skalicky, M., maximum power in termination impedors, **1258**
Skanavi, G. I., dielectrics, **1372**
Skipper, R. E., with others, moisture aging of powder-core toroids, **2355**
Skomal, E. N., with C. I. Beard, *RC* commutator for signal/noise improvement, **2784**
Skudrzyk, E., with V. Met, small apparatus using $BaTiO_3$ oscillator for ultrasonic testing of materials, **1756**
Skwirzynski, J. K., response of vestigial-sideband system to 'sine-squared' step transition, **1066**
Slade, B. N., point-contact transistors, **2487**, control of frequency characteristics and stability of, **884**
——with G. M. Rose, transistors operate at 300 Mc/s, **585**
Slater, J. C., soluble problem in energy bands, **391**
Slattery, T. G., detection of sine wave in noise by means of nonlinear filter, **206**
Slavin, W., with others, portable 250-kV accelerators, **3679**
Slichter, W. P., and E. D. Kolb, impurity effects in thermal conversion of Ge, **116**; solute distribution in Ge crystals, **3343**
Slonczewski, T., servo system for heterodyne oscillators, **2378**
van Slooten, J., mechanism of synchronization of *LC* oscillators, **2940**
Smale, J. A., with A. W. Cole, picture transmission by radio, **558**
Small, G. F., u.h.f. filters and switches for London/Birmingham television relay link, **951**
Smart, J. S., with L. N. Howard, specific heat discontinuity in antiferromagnets and ferrites, **3623**
Smelt, J. A. M., with others, steel c.r. tube for television receivers, **3132**
Smit, J., with others, ferromagnetic properties of ferroxdure materials, **751**
Smith, B. D., coding by feedback methods, **3414**
Smith, E. K., Jr, and S. Weintraub, constants in formula for atmospheric refractive index at r.f., **1990, 3287**
Smith, F. G., radio stars, ionospheric refraction of 81·5-Mc/s waves from, **407**, determination of position of, **1329**, measurement of diameter of, **1330**
——with K. E. Machin, occultation of radio star by solar corona, **98**
Smith, H. M., estimation of absolute frequency in 1950–1951, **(A)153, 1058**; quartz clocks of Greenwich time service, **3354**
Smith, J. J., vector potential derivation from scalar potentials, **(A)2285, 3574**; tables of Green's functions, Fourier series and impulse functions, **2360**
Smith, J. P., with F. A. Benson, characteristics of corona stabilizer tubes, **3155**
Smith, J. R., with R. Anderson, delayed-trigger oscillograph for television waveforms, **1438**
Smith, J. S., bandwidth of multiplex channels, **3103**
Smith, K. D., properties of junction transistors, **2490**
Smith, P. B., with others, magnetic viscosity under discontinuous and continuous field variations, **123**
Smith, P. H., charts for coaxial-line probe measurements, **458**
Smith, P. W., Jr, velocity of sound, errors in indirect measurements of, **916**, measurement of, **1566**
Smith, R. A., equation connected with theory of triode oscillations, **971**
Smith, S. T., and H. E. Brown, direct-viewing memory tube, **3760**
Smith, V. G., with J. Kates, Scotch-plaid raster for c.r. tube digit storage, **3649**
—— with A. G. Ratz, gating method for parallel computers, **2374**
Smith, W. V., with others, line breadths of microwave spectrum of O_2, **91**
Smith-Rose, R. L., survey of British research on wave propagation with particular reference to television, **1109**; U.R.S.I. meeting in Sydney, **2521**
Smith-White, W. B., Poisson-Kelvin hypothesis and theory of dielectrics, **994**
Smolenski, G. A., dielectric properties of zirconates, stannates and titanates of bivalent metals, **433**
Smyth, M. J., solar corona and geomagnetism, **1326**
Smythe, W. R., current distribution in cylinders, **1650**
Snel, D. A., magnetic sound-recording equipment, **2551**
Snider, R. H., with others, high-speed direct-scanning facsimile system, **(A)841, 3730**
Snow, H. A., with others, counter-circuit multiplex receiver, **3099**
Snow, W. B., a.f. input circuits, **2615**
Synder, H. S., with others, strong-focusing synchrotron, **1454**, origin of, **3678**
Snyder, R. L., Jr, input-output system of EDVAC, **2371**
Soanes, S. V., problems in a.f. spectrum analysis, **(D)776**; response of *RLC* circuits to linear-frequency-sweep voltage, **(D)2930**
Sobel, A., with H. T. Sterling, constant-current a.f. power amplifier, **1635, 2609**
Söding, H., rigorous basis of intermodulation method of nonlinear-distortion measurement, **3059**
van Soest, J. L., symposium on noise, historical introduction, **908**
Sogn, L. T., and P. A. Simpson, loading of quartz oscillator plates, **966**
Sohon, H., wide-band phase-delay circuit, **3192**
Sokal, N. O., cathode-follower design charts, **3565**
Soldi, M., thermistors in r.f. bridge for low admittances, **1748**
Solntsev, G. S., M. Z. Khokhlov and E. A. Rodina, single-electrode discharge at 31·7 Mc/s, **1307**
Somayajulu, Y. V., coefficient of recombination in ionosphere, **2653**
Somers, E. V., propagation of acoustic waves in liquid-filled cylindrical hole, **2858**
Somerville, J. M., sparking potentials in transverse magnetic field, **84**
Somerville, T., and C. L. S. Gilford, composite c.r.o. displays of acoustic phenomena, **307**
Sommer, J., new commercial barretters, **646**
Sommerman, G. M. L. with P. B. Jacob, Jr, dependence of breakdown direct voltage on humidity and time, **2290**
Sorger, G., with R. Feldtkeller, magnetic after-effects, **2041**
Soria, R. M., C. C. Camillo and J. G. Krisilas, liquid-dielectric r.f. coaxial cables, **3472**
Sosin, B. M., combining filter for common-aerial vision and sound transmission, **1162**
Sourdillon, M., Boys-camera study of lightning discharges, **1682**
Sparks, I. L., and H. R. Philipp, retarding-potential method for measuring conductivity of oxide-coated cathodes, **2835**
Sparrow, E. L., with others, synthesis of cascaded 3-terminal *RC* networks, **656**
Spaven, W. J., high-*Q* measurement, **464**
Spears, R. A., design and applications of quartz-crystal units, **441**
Speer, F., with H. Gobrecht, measurement of secondary emission, **3581**
Spence, R. D., with E. Hiedemann, coherent theory of relaxation phenomena, **694**
Spencer, D. E., with P. Moon, coordinate systems associated with elliptic functions, **3347**
Spencer, N. W., with others, dynamic probe measurements in ionosphere, **3291**
Spencer, P. L., grid-type magnetron for modulation at u.h.f., **2519**
Spencer, R. H., transistor-controlled magnetic amplifier, **3211**
Spilsbury, R. S. J., Rugby standard-frequency transmissions, **1732**
Spindler, C. W., Jr, all-triode electronic switch, **343**
Spindler, W., with E. Zwicker, influence of nonlinear distortion on audibility of frequency vibrato, **2870**
Sponable, E. I., eidophor system of theatre television, **2474**
Spooner, D. J., problems in design of marine transmitters, **3443**
Springer, A. M., apparatus for continuous very-long-period recording of sound, **3180**
Sprinkle, M. C., with D. Sarser, 'Maestro' a.f. power amplifier, **978**
Sproson, W. N., M. Gilbert and W. West, fundamental aspects of colour television, **1814**
Sproull, R. L., with E. M. Pell, recording a.c.-Hall-effect apparatus, **1057**
Squires, W. K., and R. A. Goundry, constant-input-impedance second detector for television receivers, **254**
—— and H. L. Newman, video amplifiers with optimum transient response, **3133**
Srinivasan, D., with others, dependence of sonic intensity at source on absorption coefficient in liquids, **2543**
Stafiychuk, E. A., with others, effect of polarizing field on dielectric properties of $BaTiO_3$, **112**
Stahl, R. J., and G. A. Walters, noise reduction in intercommunication systems, **2787**
Stahmann, J. R., with others, aircraft radio-interference measurements, **2075**
Staley, R. C., with K. H. Jehn, correlations of 100-Mc/s propagation with meteorological effects, **2772**
Standing, K. G., and R. W. Peelle, improvement of resolution of scintillation counters, **2107**
Stansel, F. R., transistor-amplifier, formulae for, **1601**, common-collector, at carrier frequencies, **3518**
Stanworth, J. E., tellurite glasses, **143**
Staras, H., scattering of e.m. energy in randomly inhomogeneous atmosphere, **804**
Stark, J., experimental investigations on the nature of light, **1292**
Starke, C., with H. Severin, diffraction of sound waves by circular apertures, **1557**
Starks-Field, A. B., timebases, reactive, for television receivers, **860**, negative-feedback, stability in, **2272**
Starodubtsev, S. V., with others, action of electron stream on current sensitivity of Se and Ag_2S photocells, **3140**
Starr, A. T., Radio and Radar Technique, **(B)2854**
—— and T. H. Walker, design of microwave radio links, **217**
Starynkevitch, D., design of ladder filters, **1932**
Steele, E. L., current gain in *p-n-p*-junction transistors, **881**
Steele, M. C., number theory and magnetic properties of electron gas, **992**
van Steenis, O. L., with others, steel c.r. tube for television receivers, **3132**
Stegen, R. J., u.h.f. television radiators using slot arrays, **2900**
Steimel, K., solution of 'Rukop problem' for arc and dynatron oscillators, **2602**
Stein, N., with W. H. Hannahs, printed unit assemblies for television, **352**
Stein, S., with others, graphical analysis of two-port waveguide junction, **3191**
Steinberg, J. L., radio-noise receivers, **3402**
—— with others, radio observations of eclipses on 1st Sept. 1951 and 25th Feb. 1952, **94**; distribution of radio brightness on solar disk at 9·35 kMc/s, **3272**
Steinbuch, K., electronic switching elements in communication engineering, **48**; channel separation in p.p.m., **1788**
Stenoien, J. O., with others, microwave measurements on metal powders suspended in wax, **2326**
Stenzel, H., sound field of rectangular piston membrane, **1877**
Stephens, G. L., Radio Interference Suppression, **(B)818**
Stephenson, I. M., with A. L. Cullen, torque-type wattmeter for 3-cm microwaves, **1082**
Stephenson, J. D., and others, c.r. tubes and valves for television receivers, **1521**
Sterling, H. T., and A. Sobel, constant-current a.f. power amplifier, **1635, 2609**
Sternberg, R. L., and H. Kaufman, theory of multiple nonuniform transmission lines, **1581**

World Radio History

Sterner, J. F., wide-range frequency calibrator, **1751**
—— with J. A. Cornell, frequency-sweep oscillator for u.h.f. television band, **487**
Sternheimer, R. M., double focusing of charged particles with wedge-shaped magnetic field, **1456**
Stevels, J. M., power factor of glasses as function of composition, **443**
Stewart, R. M., Jr, and A. R. Kassander, Jr, electronic statistical tabulator, **2369**
Stibbé, H., microphony in superheterodyne oscillators, **814**
Stiber, S., ferrite cores in electronic tuning of r.f. circuits, **3569**
Stieltjes, F. H., with A. J. W. M. van Overbeek, bandwidth limit of junction transistors, **3747**
Stigmark, L., determination of charge on electron from shot-noise measurements, **1959**
Stilwell, G. R., with F. W. Reynolds, mean free paths of electrons in evaporated Cu and Ag films, **714**
Stjernberg, B. K. E., with others, microwave propagation in optical range, **3097**
Stockinger, F., motions of particles in field of electromagnet, **1663**
Stockman, H., inherent feedback in triodes, **1865**; degenerative pentode equivalent circuit, **2611**
Stöhr, H. J., Wien bridge as frequency-determining element in selective amplifiers, **1951**
Stone, H. A., Jr, ferrite-core inductors, **1923**
Stone, W. M., statistical theory of detection of randomly modulated carrier, **3602**
Storch, L., note on network theorem, **1607**; design of Π-network aerial couplers, **(D)2588**; response characteristics, **(D)3222**; theorem on impedance-transforming properties of reactive networks, **3541**
Storer, J. E., L. S. Sheingold and S. Stein, graphical analysis of two-port waveguide junction, **3191**
Storey, L. R. O., ultrasonic absorption in mixtures of ethyl alcohol and water, **1222**
Storm, H. F., steady-state operation of saturable reactors with inductive d.c. load, **3527**
Stout, V. L., luminescence and thermionic emission of BaO, **1712**
Stover, J. S., operational experience with split-channel 50-Mc/s system, **3710**
Strafford, F. R. W., receiving aerials for British television, **1237**
Straiton, A. W., reflection of microwaves from ground and water surfaces, **1787**
—— with others, dielectric constant measurements at λ 8·6 mm, **3655**
Stram, O., with H. Epstein, magnetostrictive ultrasonic delay line, **2057**
Strandberg, M. W. P., with J. R. Eshbach, Zeeman-effect measurements on microwave spectra, **1318**
Strasberg, M., effects of terminations on insertion loss of ladder filters, **2596**
Strässer, C., with L. 't Hart, modern transmitting equipment for merchant ships, **2818**
Strauss, H. E., channel spacings at 152 to 174 Mc/s, **3102, 3706**
Strazza, L. E., v.h.f. multiplex radio system in Nyasaland, **1485**
Street, R., J. C. Woolley, and P. B. Smith, magnetic viscosity under discontinuous and continuous field variations, **123**
—— with others, antiferromagnetic properties of CoO-MnO mixtures, **2343**
Stride, P. L., search radar for civil aircraft, **109**
Stringer, J. B., with M. V. Wilkes, micro-programming in digital computer, **2716**
Strohfeldt, M., R. W. E. McNicol and G. de V. Gipps, ionosphere measurements at oblique incidence over eastern Australia, **807**
Ströle, D., design of control systems, **1760**
Stroobants, P., optimum number of lines for television system as dependent on size of receiving screen, **844**
Strull, G., CdS as crystal rectifier, **3136**
Strum, P. D., crystal mixer performance, **2941**
Struthers, J. D., with C. S. Fuller, Cu as acceptor element in Ge, **119**
Strutt, M. J. O., methods of reducing noise/signal ratio at output terminals of amplifiers, **976**
Stuetzer, O. M., transistors in aircraft equipment, **672**; junction fieldistors, **880**
Stuhlmann, W., equipment for inductive heating shown at 1952 Technical Fair, Hanover, **178**
Stuke, J., absorption and reflection of amorphous and hexagonal Se, **2019**
Stumpers, F. L., signal/noise ratio for various modulation systems, **828**
Sturley, K. R., electronic switch, **654**
Sturrock, P. A., imaging properties of electron beams in static e.m. fields, **1657**
Stuwe, G., with A. Scholz, frequency markers and scales for visible-indication instruments, **1077**
Stuyts, A. L., G. W. Rathenau and E. W. Gorter, preferred crystal orientation in ferromagnetic ceramics, **1036**
—— with others, ferromagnetic properties of ferroxdure materials, **751**
Styles, R. S., and F. W. Campbell, radar observations of rain from non-freezing clouds, **2004**
Suchet, J., with N'Guyen Thien-Chi, voltage regulators using nonlinear elements, **230**
van Suchtelen, H., ferroxcube aerial rods, **939**; losses in ferroxcube rods and tubes, **3636**
—— with others, effects due to curvature of valve characteristics, **1854**
Suchy, K., wave optics and ray optics in inhomogeneous anisotropic absorbing media, **2954**; effect of geomagnetic field on ionospheric absorption of short waves, **1678**
Sucksmith, W., magnetic properties of stainless steel wire, **1708**
Suddeth, J. A., with others, electron-beam interferometer, **3074**
Sueur, F., 16th plenary assembly of C.C.I.F., Oct. 1951, Florence, **1120**
Sugita, T., with E. Yamaka, energy-band structure in Si crystal, **3327**
Sugiura, M., e.m. shielding effect of ionosphere, **2867**
—— M. Tazima and T. Nagata, anomalous ionization over auroral zone during magnetic storms, **2991**
Suhl, H., magnetic effects on noise in Ge filament, **2695**
—— and L. R. Walker, Faraday rotation of guided waves, **(C)1232**
Suhrmann, R., and C. Kangro, semiconductor properties of systems K-Sb, Cs-Sb, K-In, Cs-In, **2030**
Sullivan, A. W., 'ogiver' radio-noise meter, **1443**
—— and J. M. Barney, nonlinear statistical filter, **667**
Sulzer, P. G., reliable locked-oscillator pulse timer, **2945**; precision transistor oscillator, **3051**; junction-transistor circuit applications, **3244**; low-distortion audio oscillator, **3517**
Suran, J. J., with W. F. Chow, transient analysis of junction-transistor amplifiers, **3513**
Surduts, A., Faraday effect in conductors and semiconductors, **2299**; u.h.f. measurement of dielectric constant and complex permeability, **2381**
Süsskind, C., isotropic artificial dielectric, **(D)113**
Sutcliffe, H., transmission-line impedance measurements, **2733**
Suzuki, H., with others, temperature dependence of zero-bias resistance of Cu_2O rectifiers, **3345**
Suzuki, T., with T. Nagata, solar-flare type of variation of geomagnetic field and integrated conductivity of ionosphere, **2664**
Swann, W. F. G., fundamental theory of electrets, **3257**
Swerling, P., with E. Reich, detection of sine wave in Gaussian noise, **2429**
Swift, W. B., and T. J. Higgins, e.m. propagation in waveguides of rhombic cross-section, **2883**
Swihart, J., and E. Akeley, axial motion of electrons in linear accelerator, **3077**
Swingle, D. M., abacs for tropospheric refractive index, **1670**
Syeles, A. M., with others, permanent magnet from powdered MnBi, **1035**
Symon, E., with others, electronic tachometer, **2747**
Szegho, C. S., with others, rotating-screen colour-television tube, **3740**
Sziklai, G. C., symmetrical properties of transistors, **2583, 3213**
—— R. D. Lohman and G. B. Herzog, transistor circuits for television, **2813**

Ta-You Wu. See Wu, Ta-You.
Taeger, W., analysis of three types of valve amplifier circuit, **1632**; i.f. amplifiers with bifilar coils, **3735**
Tafel, H. J., print-through effect in magnetic tape, **1901**
Taft, E. A., and L. Apker, photoemission from Cs_2Te and Rb_2Te, **1689**
—— with L. Apker, field emission from photoconductors, **1391**; photoconduction in anodic Ta_2O_5, **733**
—— with others, electron scattering and photoemission from Cs_3Sb, **1690**
Tagholm, L. F., and G. I. Ross, selection and testing of sites for television transmitters in United Kingdom, **1172**
Taglang, P., with A. J. P. Meyer, influence of magnetic field on polymorphic transformation in a ferromagnetic material, **2339**
Tai, C. T., e.m. back-scattering from cylindrical wires, **36**
Takahasi, H., with others, hysteresis loops of $BaTiO_3$ ceramic at h.f., **3012**
Takakura, T., directivity of radio emission from sunspots, **1981**
—— with others, dielectric constant of Rochelle salt at 3 kMc/s, **2729**
Takeda, A., with G. Shirane, transition energy and volume change in $BaTiO_3$, **2053**
Takeda, I., with S. Yoshida, secondary emission from oxide cathodes, **2886**
—— with others, dissociation of oxide-coated cathode, **2334**
Tamm, K., and I. Pritsching, frequency analyser with mechanical filter, **1227**
—— with G. Kurtze, measurements of sound absorption in water and aqueous solutions of electrolytes, **2196**
—— with E. Meyer, wide-band absorbers for liquid-borne sound, **1569**
Tauenbaum, M., with G. L. Pearson, magnetoresistance effect in InSb, **2896**
Tanner, W. E., miniaturization of airborne filter chokes, **1924**
Taplin, J. F., with W. R. Ahrendt, Automatic Feedback Control, **(B)840**
Tartakovski, B. D., and M. M. Efrussi, testing sound-absorbing materials, **3466**
Tasny-Tschiassny, L., initial conditions in transient analysis, **1247**
Tavernier, P., and P. Prache, effect of pressures on resistance of thermistor, **342**
Taylor, C., with others, synchronization of pulsed high-energy ion beams, **1448**
Taylor, D., industrial applications of nucleonics, **495**
Taylor, H. O., tube method of measuring sound absorption, **925**
Taylor, J. C. E., with W. B. W. Alison, direct-reading thermistor bridge, **(D)2740**
Taylor, N. W., relativistic e.m. equations, **707, 1956**
Taylor, R. C., and C. U. Watts, filter characteristics by direct method, **(A)961, 3544**
Taylor, W. E., N. H. Odell and H. Y. Fan, grain-boundary barriers in Ge, **1406**
—— with L. Roth, preparation of Ge single crystals, **744, (C)1408**
Tazima, M., with T. Nagata, solar-flare type of variation of geomagnetic field and integrated conductivity of ionosphere, **2665**
—— with others, anomalous ionization over auroral zone during magnetic storms, **2991**
Tchernicheff, A., rounding of signals by filter in radiotelegraphy transmitter, **1847**
Teasdale, R. D., and G. N. Crawford, cut-off frequency for cylindrical waveguide with coaxial dielectric rod, **2886**
—— with W. A. Edson, susceptance slope and selectivity in oscillator design, **2928**
Tebble, R. S., J. E. Wood and J. J. Florentin, temperature variation of magnetization of Ni, **1033**
Teichmann, T., and E. P. Wigner, e.m. field expansions in loss-free cavities, **2268**
Teissié-Solier, M., and J. Lagasse, generators of repeated surge waves, **1088**
Tellegen, B. D. H., network theorem, with applications, **62**; synthesis of $2n$-poles by networks with minimum number of elements, **3238**

World Radio History

Telfer, J. E., television applications in industry, scientific research, and education, **1512**, **2815**
Tellier, J. C., with G. W. Preston, lock-in performance of a.f.c. circuit, **1280**
Templeton, I. M., with B. V. Rollin, noise in semiconductors at v.l.f., **2039**
Tenger, P., equivalent Q of RC networks, **(D)3221**
Tennes, C. J. with E. L. Kent, electronic musical instrument, **317**
Tenzer, R., null method for measurement of magnetic induction, **1744**
Terlecki, R., B.T.R. frequency-shift c.r. monitor, **1436**
Terletski, Ya. P., with A. A. Korchak, e.m. radiation from cosmic protons and r.f. radiation from galaxy, **1331**
Terris, A., with others, properties of ferrites at v.h.f., **1312**
von Tersch, L. W., and R. L. Doty, automatic ejection from betatrons and synchrotrons, **3677**
Tetzner, K., transmitter and studio for private u.s.w. stations, **2178**
Teves, M. C., and T. Tol, electronic intensification of fluorescopic images, **1038**
Teviotdale, A., Zener's theory of ferromagnetism, **1002**
Tharp, N. B., multiplex microwave system, **3107**
Thaxton, H. M., with others, autocorrelation function from ergodic hypothesis, **535**, for teleprinter signals, **537**
Thayer, R. E., auroral effects on television, **1173**
Thayer, W., Jr, with J. S. Brown, high-Q a.f. resonant filters, **351**
Thedieck, R., forming of Ge surfaces, **3360**; mechanism of point-contact transistor, **3331**
Theile, R., signal generation in television camera tubes, **1828**, **1829**, **3433**
—— and H. McGhee, secondary-electron multipliers in image iconoscopes, **855**
Theunissen, F. A. P. M., noise of metal contacts, **3498**
Thiele, R., with others, improvement of audibility in a theatre, **1572**
Thien-Chi N'Guyen. See N'Guyen, Thien-Chi.
Thiessen, G., magnetic field strength in sunspots, **2303**
Thinius, E., equalizing action of bridged-T networks, **2254**
Thirup, G., measuring complex voltage ratios in range 1–100 Mc/s, **1735**
—— and F. A. Vitha, measuring complex voltage ratios at 1–100 Mc/s, **2731**
Thomas, A. B., design of peaking transformer, **2233**; principles and operation of gas-filled counter tubes, **3763**
Thomas, D. E., transistor amplifier cut-off frequency, **689**; low-drain transistor a.f. oscillator, **679**
Thomas, E. E., with others, observations of dislocations in Ge boundaries, **2693**
Thomas, L. A., modern trends in communication material, **3635**
Thomas, P. A. V., synchronizing circuit for variable input voltages, **339**; analogue reciprocal-function unit for pulse signals, **2946**
Thompson, A. P., and J. R. Musgrave, production, properties and applications of Ge, **1405**
Thompson, G. T., with J. E. Houldin, h.f. bridge with variable ratio arms, **1433**
Thomson, A. G., properties and applications of PVC, **1720**
Thomson, W. E., networks, with maximally flat delay, **(C)54**, with sine-squared impulse response, synthesis of, **348**, **(D)1609**; theory of time series for waveform-transmission systems, **959**
Thon, W., with others, radiation by fast electron beams, **3582**
Thrower, C. V., with H. H. Woodson, compensation of magnetic-amplifier servo system, **3114**
Thurston, E. G., sensitivity of circular bimorph transducer, **926**
Thurston, G. B., absolute measurement of impedance of acoustic elements, **917**
Tierney, W. L., radio relay stations of the TD-2 system, **216**
van Tilburg, P., and J. A. Verhoef, ferroxdure focusing unit for television picture tubes, **862**
Tillman, J. R., J. Butterworth and R. E. Warren, frequency dependence of mutual conductance of aged oxide-cathode valves, **(A)2838**
—— with H. G. Bassett, transient effects in point-contact transistors, **2491**
Tipple, P. M., with others, contact properties of p-type Ge, **117**
Tischer, F. J., video amplifiers, amplification and bandwidth of, **69**, relations between amplitude and phase distortions in, **980**, effective bandwidth of, **1947**, with extreme bandwidth, **2275**; helical measurement line for microwaves, **779**
Tod, D. S., with F. Hollinghurst, specification and testing of television wire-broadcasting systems, **1755**
Toitot, M., and A. Boulloud, discharge between positive point and plane in compressed air, **3265**
Tol, T., with M. C. Teves, electronic intensification of fluoroscopic images, **1098**
Tolbert, C. W., with others, dielectric-constant measurements at λ 8·6 mm, **3655**
Tolpygo, K. B., determination of mass of current carriers in semiconductors, **1381**
—— and I. M. Tsidil'kovski, thermal rectification effect, **3015**
Toman, K., W. G. Albright and E. C. Jordan, meteorological effects on v.h.f. propagation, **1784**
Tombs, D. M., 3-dimensional locus curves for oscillatory circuits, **2266**
Tomiyasu, K., and S. B. Cohn, Transvar directional coupler, **2931**
Tomlinson, T. B., space-charge reduction of l.f. fluctuations, **281**; temperature dependence of flicker effect, **3150**
Tomovich, R., universal unit for differential analyser, **146**
Tomura, M., and Y. Abiko, electron multiplication in hard flows of Se rectifiers, **2350**
Tønnesen, T. H., transistor properties of semiconductors, **121**
Toombs, R., with others, B.B.C. monitoring technique for unattended transmitters, **548**
Toraldo di Francia, G., with L. Ronchi, determination of reflection coefficient of stratified medium by calculus of variations, **1314**
Torcheux, É., with É. Honoré, Rana radio-navigation system, **3314**
Torikai, Y., transmission of ultrasonic waves through plane absorptive plate in liquid, **2863**
Torikai, Y., and K. Negishi, phase method of visualizing ultrasonic waves, **2865**
Toth, E., application of transistors in superheterodyne receivers, **(A)3403**
Towers, H. C., radio on Indian railways, **1122**
Townsend, G. B., incorrect interlacing in accurately synchronized television receivers, **1498**
Townsend, R., serial digit adders for variable radix of notation, **3645**
Trad, V., and R. Muniz, theatre projection television equipment, **562**
Travers, P., design of conditionally stable feedback systems, **2453**
Tredgold, R. H., with others, antiferromagnetic properties of CoO-MnO mixtures, **2343**
Treen, K. F., direct-reading thermistor bridge, **(D)3366**
Tremellen, K. W., with F. A. Kitchen, ionospheric influences in television reception, **1176**
—— with others, ionospheric propagation of v.l.f., l.f. and m.f. waves, **1781**
Trent, R. L., transistor reversible binary counter, **650**, **2243**
von Trentini, G., new e.m. lens, **937**; parabolic radar aerial with rotating beam, **1245**; polystyrene and lucite rod aerials, **3479**; grids as circuit elements for e.m. waves in space, **3483**
Trickett, E. S., with L. K. Wheeler, measurement of spray particles, **3681**
van Trier, A. A. T. M., Faraday rotation of guided waves, **2890**
Trigg, R. D., voltage stabilization with series valve control, **2802**; simplified treatment of phase-shift networks, **3230**
Troitski, V. S., sensitivity of radio thermometers, **2761**
Trolan, J. K., with others, field emitter, **3082**
Trolese, L. G., J. P. Day and R. U. F. Hopkins, propagation phenomena on microwave line-of-sight links, **1785**
Trost, A., with R. Berthold, G-M counter arrangement for X-ray interference measurements, **799**
Truell, R., and J. A. Bronzo, ultrasonic-attenuation measurements in Ge, **2694**
Truesdell, C., critical λ of ultrasonic waves in viscous fluid, **302**
Truxal, J. G., and J. N. Warfield, synthesis of dynamically variable electronic filter, **2925**
—— with R. S. Carlson, synthesis of compensation networks for carrier-frequency servomechanisms, **3115**
Tsaï, B., with others, thermomagnetic properties of haematite, **2705**
Tsidil'kovski, I. M., with K. B. Tolpygo, thermal rectification effect, **3015**
Tsukkerman, P. I., nonoptical theory of focusing in rotating magnetic fields, **3580**
Tubota, H., with others, temperature dependence of zero-bias resistance of Cu_2O rectifiers, **3345**
Tucker, D. G., rectifier modulators, with frequency-selective terminations, input impedance of, **579**, carrier-leak control in, **580**; nonlinearity in voltmeter using cathode follower, **1746**
Tucker, M. J., electronic square-law circuit for graphic recording, **346**
Tukizi, O., frequency of scintillation fading of microwaves, **3098**
Tung, S. P., solution of linear servomechanism by means of equivalent network, **550**
Turkevich, J., with S. Larach, interaction of Mn activator ions in Zn_2SiO_4-Mn phosphors, **2323**
Turlier, R., with G. Raoult, u.h.f. oscillations in triode valves, **2271**
Turnbull, J. C., high-conductivity glass/metal seal, **142**
Turner, D. R., analysis of waves containing harmonics up to twelfth, **1427**
Turner, E. H., nonreciprocal waveguide medium using ferrites, **2922**
Turner, F. T., and others, high-speed direct-scanning facsimile system, **(A)841**, **3730**
Turner, L. B., two electronic resistance or conductance meters, **(A)170**
Twersky, V., multiple-scattering theory of finite grating, **695**
Twiss, R. Q., e.m. propagation in electron-ion streams, **1316**
Tyler, V. J., simple bolometer for dissipation measurements, **484**
Tyminski, W. V., and A. E. Hylas, wide-band hybrid ring for u.h.f., **960**
—— with A. E. Hylas, u.h.f. grid-dip meter, **2080**

Ueta, M., field emission of crystalline phosphors, **3321**
Uitjens, A. G. W., h.f. and i.f. television amplifiers, gain and bandwidth of, **1639**, noise problems of, **1640**, effects of feedback in, **1954**
—— with C. J. Boers, line-timebase output stages with booster circuit, **2478**
—— with others, new trends in a.m./f.m. receiver design, **2427**
Ulrich, R. P., with others, evaporated-point-contact rectifiers, **2179**
Uminski, S., harmonic distortion and negative feedback, **(D)3253**
Unger, H. G., plane reflectors for directive aerials, **936**
Unwin, R. S., with H. G. Hay, tropospheric wave propagation duct of non-uniform height, **1471**
Unz, M., high-resistance bridge for conductivity measurements, **3365**
Urban, P., with E. Ledinegg, theory of waveguides, **1582**; theory of forced oscillations in electrodynamic systems, **1622**; first boundary-value problem of Maxwell's equations, **1641**; bandwidth of cm-λ band-pass filters, **1935**; susceptibility of linear antiferromagnetic chain, **2633**
Urkowitz, H., ferroelectric amplifier, **1283**
—— with T. S. George, noise in microwave superregenerative amplifier, **1948**
Uyeda, H., studies on ionospheric storms, **2988**
—— and Y. Arima, classification of F_2-layer storms, **2983**
—— and T. Obayashi, field-strength calculations for long transmission paths, **2778**
—— K. Miya and T. Kobayashi, frequency of occurrence of fE_s and $f_{min}F$, **2985**
—— and others, $h't$ ionosphere measurements at Wakkanai, Japan, during eclipse of 9th May 1948, **2659**
—— with others, frequency-sweep $h'F_2$ measurements, **3297**

Vaage, E. F., transmission properties of Clogston-type conductors, **2562**

World Radio History

Vainshtein, L. A., and L. P. Malyavkin, alternating component in photocurrent under strong illumination, **3138**
Vakin, S. A., propagation along helical slit, **3476**
Valdes, L. B., measurement of minority-carrier lifetime in Ge, **741**; electrode spacing and base resistance of transistors, **882**
Valensi, G., compatible systems of colour television, **1815**
Valeton, J. J. P., h.v. generators for projection television, **569**
Valladas, G., and A. Leveque, background noise in ionization-chamber amplifiers, **1634**
Vallarino, A. R., H. A. Snow and C. Greenwald, counter-circuit multiplex reciver, **3099**
Valle, G., theory of discharge potential for coaxial cylindrical electrodes, **1655**
del Valle, G. A., and L. W. Ferber, wear of magnetic heads, **2203**
Vallet-Cerisier, L. A., coupling of cathode followers in d.c. amplifiers, **3252**
Vander Sluis, K. L., with others, determination of velocity of light by band-spectrum method, **987**
Vanet, P., with W. W. Jennings, direct-vision stereo-projection screen, **375**
Vannel, —, with — Macelloni, control towers for civil aviation, **3419**
Van Rennes, A. B., pulse-amplitude analysis in nuclear research, **639**
—— with W. M. Grim, effects of grid/cathode capacitance in pulse-height selectors, **941**
Van Winkle, D. M., with R. G. Shulman, pressure-welded Ge *p-n* junctions, **2034**
Vasil'ev, E. I., and V. M. Lopukhin, theory of helix-type travelling-wave valve, **3453**
Vasseur, J. P., diffraction by apertures in conducting screens, **710**; distortion of f.m. wave, **2141**
Vassilian, M., with C. Biguenet, gas-filled valves for industrial applications, **295**
Vastel, J., 3–4-MeV linear electron accelerator, **2407**
Vauthieu, P., numerograph, **1728**
Vautier, R., magnetostriction of Co ferrites, as function of composition, **131**, temperature variation of, **132**
Vavilov, V. S., electron-optical investigation of photoconductive effects, **3606**
Vawter, F. E., with others, scattering of 56-Mc/s radio waves from lower ionosphere, **2119**; radio reflections from aurora, **3308**
Vegard, L., advances in auroral spectroscopy, **1017**
Veinott, C. G., MONECA, a motor-performance calculator, **765**
Veith, F. S., with others, performance of vidicon camera tube, **249**
Veldkamp, J., with J. Bartels, international data on magnetic disturbances, first quarter 1952, **401**, second quarter 1952, **1340**, third quarter 1952, **1989**, fourth quarter 1952, **3285**
van Velthoven, T. M. W., c.r. oscilloscope, Type GM.5660, **3370**
Venema, H. J., shunt conductance of waveguide-fed slot, **323**
Venzke, G., sound absorbers for television studios, **3174**
Verhagen, C. M., survey of limits in d.c. amplification, **2277**
Verhoef, J. A., with P. van Tilburg, ferroxdure focusing unit for television picture tubes, **862**
Vermeulen, R., dimensional analysis, units and rationalization, **3584**
Vernier, P., optical and photoelectric properties of PbS layers, **2706**
Vernon, F. L., Jr, applications of microwave homodyne, **1741**
Vernon, T. V., with A. G. Milnes, saturable-core reference source for magnetic amplifiers, **2237**
Vernotte, P., successive differentiation of experimental curves, **2619**
Veronda, C., klystron pulse amplifier for 960–1215 Mc/s, **595**
Verweel, J., magnetrons, **1209**
Verzaux, P., transmission of radio waves through highly ionized gases, **3268**
Vestine, E. H., variations of geomagnetic field, and rate of earth's rotation **1338, 3281**
Veszi, G. A., modern single-layer Se photocell, **3449**
Vigean, F., alternating-field excitation of electroluminescent substances, **2282**
Vigneron, H., measurement of characteristics of r.f. cable, **158**
Vilenski, I. M., theory of interaction of radio waves in ionosphere, **3095**
Villard, O. G., Jr, and F. S. Holman, electrically tuned *RC* oscillator or amplifier, **1638**
—— and A. M. Peterson, scatter sounding, a new ionospheric technique, **201**; extended-range communication in 15- and 20-m bands, **2421**
—— and others, transmission by reflection from meteoric ionization, **2117**
—— with others, double-Doppler investigation of meteor-trail echoes, **393**
Ville, J. A., analytical signals with limited spectrum, **2137**
—— with R. Roch, transmission parameters of a cable amplification section, **2559**
Villiers, —, radio aids to air navigation, **3419**
Vine, B. H., R. B. Janes and F. S. Veith, performance of vidicon camera tube, **249**
Visokovski, D. M., investigation on models of aerials with directors, **2893**; end-fire aerial arrays, **2901**
Visser, S. W., extrapolation of sunspot/climate relations, **3595**
Vitale, B., ionic equilibrium of lower atmosphere, **719**
Vitha, F. A., portable pulse test-set for coaxial cables, **3361**
—— with G. Thirup, measuring complex voltage ratios at 1–100 Mc/s, **2731**
van Vliet, K. M., with J. G. van Wijngaarden, l.f. noise in valves, **1192**
—— with others, l.f. noise in valves, **1202**
Vodar, B., with C. Feldman, conduction of Pt films covered with dielectric layers, **134**
—— with others, variation of resistance of thin metal films as function of applied potential, **3339**
Vodop'yanov, K. A., and B. I. Vorozhtsov, measurement of permittivity and loss angle at u.h.f., **3656**
Voge, J., e.m.-field fluctuations due to turbulence, at end of line-of-sight propagation path, **3394**; u.s.w. fading due to inversion layers, **3695**
Vogel, F. L., and others, observations of dislocations in Ge boundaries, **2693**
Vogel, T., mathematical theory of response of quadripole to discontinuous signals, **957**; boundary conditions for acoustic wave equation, **1894**; measurement of sound-absorption coefficient, **2197**
Vogt, E., with A. Elsas, reversal of sign of magnetostriction by expansion, **1711**
Voigt, G., automatic tuning in microwave receivers, **2130**
Voigt, H., measurement bridge for 0·1–1000 Mc/s, **782**
de Voogt, A. H., calculation of ray path in ionosphere, **3691**
de Vore, C., aircraft aerial fittings reduce precipitation interference, **2895**
Vorozhtsov, B. I., with K. A. Vodop'yanov, measurement of permittivity and loss angle at u.h.f., **3656**
Vos de Wael, L. R. M., direct-reading frequency-measurement equipment for the range 30 c/s–30 Mc/s, **171**
Voss, H. H., with G. Drexler, multistage band-pass filter, with optimum approximation to rectangular response curve, **1613**
de Vrijer, F. W., recent advances in colour television, **2162**
Vural, B., f.m. telegraphy on carrier-current telephone lines, **2434**

Wachowski, H. M., with R. E. Beam, shielded-dielectric-rod waveguides, **2218**
Wächtler, M., with others, accuracy of c.r.o. direction finder, **1367**
Wada, H., with others, propagation characteristics of obliquely incident pulse waves during solar eclipse 9th May 1948, **2770**
Waddell, B. L., with others, digital to analogue converter, **148**
Wade, F., with E. E. Shelton, corona discharge tubes for voltage stabilization, **1136, (D)2803**
de Wael, L. R. M. Vos. See Vos de Wael, L. R. M.
Wagener, S., properties of oxide cathodes, **286**; sorption of gases at very low pressures by Th powder, **2675**
Wagner, H. M., cathode-interface impedance and its measurement, **3149**
Wahl, R., scale-of-ten counter using 4 double triodes, **2242**
Waidelich, W., logarithmic-scale electrometer, **3364**
Wainer, E., and C. Wentworth, niobate and tantalate dielectrics, **137**
Wait, J. R., radiation, from magnetic dipole in conducting medium, **39, 2413**; reflection of e.m. waves from inhomogeneous medium, **1466**; loop aerial with spheroidal core, **1917, 3491**; radiation resistance of small circular loop above conducting earth, **2905**; conducting permeable sphere near coil carrying a.c., **2986**; approximate method of obtaining transient response from frequency response, **3542**
—— and L. L. Campbell, fields of dipole in semi-infinite conducting medium, **2109, 3202**; effect of large dielectric constant on ground-wave propagation, **2113**
Wakai, N., with K. Miya, characteristics of ionospheric disturbances during severe magnetic storms, **2987**
—— with others, field strength of scattered waves in r.f. propagation, **2775**
Wakeman, R. P., experimental u.h.f. broadcast, **555**
Wälchli, R., h.f. heating of metals, **1452**
Wald, S., low-cost variable phase shifter, **640**
Waldmeier, M., final relative sunspot numbers for 1951, **394**; provisional sunspot numbers, April–June 1952, **395**, July–Sept. 1952, **1325**, Oct.–Dec. 1952, **1984**, Jan.–March 1953, **3275**
Waldvogel, P., with others, Swiss developments in h.f. technology, **1548**
Walker, A. H. B., transductor control of rectifier output voltage, **839**; applications of Se and Cu_2O rectifiers in television receivers, **1502**
Walker, F. M., with others, c.r. tubes and valves for television receivers, **1521**
Walker, J. G., with R. M. Bozorth, magnetostriction of Co and Ni ferrites, **1399**; magnetic crystal anisotropy and magnetostriction of Fe-Ni alloys, **2345**
Walker, L. R., starting currents in backward-wave oscillator, **3752**
—— with H. Suhl, Faraday rotation of guided waves, **(C)1232**
Walker, P. J., loudspeaker in the home, **3469**
Walker, T. H., with A. T. Starr, design of microwave radio links, **217**
Wallace, R. L., Jr, L. G. Schimpf and E. Dickten, junction-transistor tetrode for h.f., **877, 1184**
Wallis, C. M., design of l.f. constant-time-delay lines, **(A)1603, 2920**
Wallmark, J. T., influence of initial velocities on electron transit time in diodes, **1193**; photographic study of space-charge spread of reflected electron beams, **2961**
Wallor, H., with W. Kronjäger, Rhine R/T service, **542**
Walsh, E. J., with G. T. Ford, high-transconductance tubes for broad-band telephony, **293**
Walsh, J., with E. D. Whitehead, radio telemetry, **1762**
Walter, R., simple model for directional action of two vertical radiators, **3208**
Walter, S., Type-A transistors in trigger circuits, **3516**
Walters, G. A., with R. J. Stahl, noise reduction in intercommunication systems, **2787**
Walters, L. G., regenerative loops in analogue computers, **3647**
Waltz, M. C., transients in pulse response of point-contact Ge diodes, **872**
Wang, An, high-speed number generator using magnetic storage matrices, **2370**
Wanlass, C. L., static-dynamic design of flip-flop circuits, **1602**
Wannier, G. H., motion of ions in strong electric field, **376, 1649**
Warburton, J. A., with W. N. Christiansen, highly directional aerial system for scanning solar disk, **3209**
Ward, E. E., analogue computer for design of servo systems, **1055**
Ward, F. L., Helmholtz resonators in acoustic treatment of B.B.C. studio at Swansea, **309**
Warfield, J. N., with J. G. Truxal, synthesis of dynamically variable electronic filter, **2925**
Warham, J., effect of inductance on fine transfer between Pt contacts, **3495**

World Radio History

Warminsky, R., with I. Broser, electrical conductivity connected with phosphorescence of CdS crystals, **1026, 1371**
Warnecke, R., and others, amplification by space-charge waves, **278,** oscillations in whole-anode magnetron related to, **904**
—— with others, new magnetron oscillator with interdigital circuit, **2187**
Warner, A. J., properties of IN-420 chlorinated impregnant, **3633**
Warren, R. E., with others, frequency dependence of mutual conductance of aged oxide-cathode valves, **(A)2838**
Watanabe, H., with others, a.c. magnetization characteristics of a perminvar wire, **2703**
Watanabe, K., F. Marmo and E. C. Y. Inn, formation of D layer, **2652**
Watanabe, Y., with T. Nimura, effect of finite circular baffle on sound field of disk, **1555**
Wathen, R. L., early history of magnetron, **2851**
Watkins, D. A., and A. E. Siegman, helix impedance measurements using electron beam, **3753**
Watson, R. B., with others, reverberation chamber with polycylindrical walls, **922**
Watson, S. N., with others, test equipment for television transmission circuits, **1823**
Watts, A. J., with others, design of superheterodyne receiver for television, **1504**
Watts, C. B., Jr, simultaneous radiation of odd and even patterns by linear array, **40**
Watts, C. U., with R. C. Taylor, filter characteristics by direct method, **(A)961, 3544**
Watts, J. M., oblique-incidence pulse propagation at 300 kc/s, **1474**
—— with others, ionosphere recorder for 50 kc/s to 1 Mc/s, **1998**
Waverling, E., printed circuits for home radio receivers, **354**
Wax, N., space-charge requirements in ideally focused electron-optical systems, **3384**
Waymouth, J. F., optical measurements on electroluminescent ZnS, **2023**
—— C. W. Jerome and W. C. Gungle, electroluminescence, **2956**
Waynick, A. H., with others, polarization of vertically incident long radio waves, **806;** long-delay ionospheric echoes at 150 kc/s, **1992**
Weaver, C. H., with D. W. Russell, synthesis of servomechanisms by root locations, **(A)2150**
Weaver, L. E., with A. H. Roche, television frequency-translating terminal equipment for the Birmingham/Holme-Moss coaxial cable, **1149**
Webb, E. L., with others, phosphor-photocell radiation detector, **1103**
Webb, H. D., with T. R. O'Meara, phase and gain stabilization in matched-channel receivers, **2320**
Webb, R. C., constant-resistance c.r. deflection circuits, **235**
Weber, A. P., investigations on oxide cathodes with interface layer, **2833**
Weber, D., with H. Schnitger, travelling-wave valve, experimental verification of theory of, **280,** for 15-cm λ, measurements on, **2499,** reduction of noise factor in, **3754**
Weber, J., quantum theory of damped electrical oscillator and noise, **3243;** amplification of microwave radiation by substances not in thermal equilibrium, **3593**
Weber, S., with W. Kluge, pulse irradiation of composite photocathodes, **3448**
Wechsung, H., d.c./a.c. converter using valve space-charge capacitance, **1600**
van Weel, A., radio navigational aids, **2996;** susceptance valves and reactance valves as phase modulators, **3442;** measurement of group-delay time in networks, **3659**
Wehner, G., and G. Medicus, probe measurements in hot-cathode gas diodes, **381**
Weidner, H., with others, resonance in electrodeless h.f. gas discharge in magnetic field, **85**
Weighton, D., with L. Lax, gamma-control circuit using crystal diodes, **1826**
Weill, G., with J. C. Simon, longitudinal radiation of dielectric aerials, **1244**
Weill, M. C., Ge in telecommunications technique, **1850**
Weinberg, L., synthesis, of network transfer functions, **1929,** of unbalanced *RLC* networks, **2256,** of *RLC* lattice networks, **3535**
—— and L. G. Kraft, measurements of detector output spectra, **3699**
Weintraub, S., slide-rule computation of atmospheric r.f. refractive index, **1014**
—— with E. K. Smith, Jr, constants in formula for atmospheric refractive index at r.f., **1990, 3287**
Weir, E. V., operating principles of magnetic amplifiers, **332**
Weiss, A. A., solar tides in F, region, **1348**
Weiss H., with H. Kleinwächter, consequences of amplitude spectrum in pulse technology, **3105**
Weiss, M. T., and A. G. Fox, magnetic double refraction at microwave frequencies, **755**
Weissman, R., high-speed counter uses ternary notation, **50**
Welby, B. G., computer-tape reader, **1418**
Welch, A. J. E., with others, structure and properties of ferrites, **2043**
Welch, E. E., with others, phosphors for television c.r. tubes, **1869**
Weldon, J. O., 1-MW a.m. broadcasting transmitter, **2176**
Welker, H., with O. Madelung, theory of mixed semiconductors, **2028**
Weller, F., with R. Schachenmeier, refractive index of dipolar gas mixtures at dm λ, **1612**
Wells, G. M., with A. Lindell, crystal valves, **284**
Wen Yuan Pan. See Pan, Wen Yuan.
Wendt, G., electron-beam deflection systems and their aberrations, **2842**
Wenk, P., and H. Boljahn, ultrasonic tinning of Al, **801**
Wentworth, C., with E. Wainer, niobate and tantalate dielectrics, **137**
Werner, G. L., and H. Berlin, medium-cost amplifier with good performance, **979**
Werner, P. H., mechanical properties of magnetic tapes and quality of recording, **20**
Werner, W., television reception and interference, **2173**
—— with F. Kerkhof, Television, **(B)578**
Wernholm, O., 35-MeV synchrotron, **2093**
v. Werthern, W., with F. Bath, carrier-frequency cable links, **2436**
Wessels, P. S., design of slug-tuned superheterodyne receivers, **526**
West, J. C., and D. K. Partington, phase-shifting pulse generator for thyratron control, **1629**
—— and J. Potts, relation between closed-loop transient response and open-loop frequency response, **3231**
West, W., with others, fundamental aspects of colour television, **1814**
Westell, E. P. L., reduction of radiation from carrier-current circuits on overhead power lines, **1794**
Westervelt, P. J., theory of steady rotational flow generated by sound field, **1552, (C)3166**
Westmijze, W. K., studies in magnetic recording, **3471**
Westpfahl, K., with R. Müller, diffraction of e.m. waves by slit, **1971**
Wettstein, E., apparatus for bulk tests of sheet iron, **3061**
Wetzel, W. W., with L. B. Lueck, performance of high-output magnetic tape, **1576**
Whalley, W. B., design of u.h.f.-v.h.f. television receivers, **1497**
—— C. Masucci and N. P. Salz, Ge diode as video detector, **2475**
Wheeler, H. A., skin-effect chart for conducting materials, **435**
Wheeler, L. K., and E. S. Trickett, measurement of spray particles, **3684**
—— with R. O. Carter, phototelegraphy transmitter-receiver using sub-carrier f.m., **559**
Whinnery, J. R., with C. K. Birdsall, waves in an electron stream, **2498**
—— with H. R. Johnson, travelling-wave-valve oscillators, **1872, (C)3750,** with electronic tuning, **3454**
Whitby, O., and D. R. Scheuch, output analysis and alignment techniques for phase-rotation s.s.b. transmitters, **2481**
White, A. D., with M. A. Lampert, microwave technique for studying gas discharges, **3263**
White, C. F., and K. A. Morgan, dual-input parallel-T network, **3537**
White, E. S., television-receiver a.g.c. systems, **1832**
White, H. P., Type-DM70 tuning indicator for battery or mains receivers, **3456**
White, J. E., with W. P. Bartley, alterations of characteristics of oxide-cathode valves, **3755**
Whitehead, E. D., and J. Walsh, radio telemetry, **1762**
Whitehead, J. D., quasi-transverse approximation to Appleton's magneto-ionic equation, **514**
Whitehurst, R. N., with others, radiation by fast electron beams, **3582**
Whiteley, T. B., and L. R. Alldredge, photomechanical wave analyser for Fourier analysis of transient waveforms, **1439**
Whitesell, W. J., with V. A. Johnson, theory of magnetoresistive effect in semiconductors, **2329**
Whitmer, R. M., radiation from dielectric waveguide, **322**
Wichmann, H., measurement of atmospheric electric field by radioactive probe, **1681**
Wick, R. F., with others, modulators and gyrators using Hall effect in Ge, **1930**
Wickizer, G. S., field strength of station KC2XAK recorded at Riverhead, N.Y., **1113**
—— and A. M. Braaten, field strengths at 93 Mc/s over distances of 40–150 miles, **809**
—— with others, v.h.f. transmission over mountainous path, **3396**
Wickline, B. D., with R. W. Ralston, television coverage of the 1952 National Political Conventions, **3134**
Wideröe, R., theory, development and applications of betatron, **3381**
Widl, E., noise measurements on telecommunication cables, **3182**
Wieder, H. H., and N. Cass, f.m. transistor oscillator, **2938**
—— and S. Kaufman, plastic electrets, **2025, 3323**
Wiersma, R. A., voltmeter loading, **3653**
Wigan, E. R., diagnosis of distortion by means of 'difference diagram', **2383**
Wigner, E. P., with T. Teichmann, e.m. field expansions in loss-free cavities, **2288**
Wijn, H. P. J., h.f. melting of ferromagnetic semiconductors, $BaFe_{12}O_{27}$ ferromagnetic crystal, **752**
—— with others, measurement methods for properties of ferroxcube materials, **3060**
van Wijngaarden, J. G., and E. F. de Haan, l.f. noise in electrometer valves, **1185**
—— and K. M. van Vliet, l.f. noise in valves, **1192**
—— K. M. van Vliet and C. J. van Leeuwen, l.f. noise in valves, **1202**
Wild, W., U.v. Kienlin and H. Simon, aerial systems for 24-channel p.p.m. beam R/T system, **822**
Wilde, H., mutual-inductance bridge for measurements on ferromagnetic cores, **460;** h.f. wattmeter with dry rectifier, **1752**
Wilhelm, H. T., impedance bridges for megacycle range, **169**
Wilkes, M. V., 'floating address' system for digital computer, **1722**
—— and J. B. Stringer, micro-programming in digital computer, **2716**
Wilkinson, D. H., space-charge sheath in G-M counters, **798**
Willard, G. W., ultrasonic waves measure properties of polymers, **3072**
Williams, C. E., utility factor in circuit diagrams, **63, 671**
Williams, E. J., and N. H. Kloot, interpolation in series of correlated observations, **2362**
Williams, E. M., with J. Kukel, helical-winding structures in exponential-line pulse transformers, **2234**
Williams, F. C., and G. B. B. Chaplin, design of transistor trigger circuits, **2914**
Williams, G. C., with F. L. Jones, low-pressure breakdown of gases in nonuniform fields, **2630**
Williams, H., with R. J. Halsey, Birmingham/Manchester/Holme-Moss television cable system, **1147**
Williams, H. J., magnetic domains, **749**
Williams, M. B., and D. Brookes, cable-fault indicator, **2392**
Williams, M. O., inertia effects in cold-cathode valves, **903**
Williams, P. B., with D. J. Plach, horn-loaded loudspeakers, **314**
Williams, R. B., Jr, continuous-indicating loran, **2319, 2998**

World Radio History

Williams, R. C. G., industrial and professional applications of television technique, **1844**
Williams, R. W., and G. M. Parker, source of continuously variable voltage for computer, **1056**
Williams, W. E., Jr, high-power square-pulse generator, **1086**
Williamson, E. M., with H. T. Flint, relation of quantum theory to gravitation and electromagnetism, and application to theory of electron, **3570**
Willis, B. T. M., crystal structure and antiferromagnetism of CrSb, **3036**
—— and H. P. Rooksby, crystal structure and antiferromagnetism in haematite, **1311**
Wills, M. S., rotating-coil fluxmeter, **1430**
Willwacher, E., noise factor and its relation to sensitivity of superheterodyne receiver, **2127**; grounded-grid disk-seal triode, self-excitation with, **3245**, circle diagram for input admittance of, **3564**
—— with H. Rothe, limiting sensitivity of amplifier valves, **1538**
—— with others, dm-wave beam radio equipment FREDA I, **2160**
Wilson, A. E., with L. J. Rueger, N.B.S. microwave standard-frequency service, **2063**
Wilson, L. T., with N. F. Roberts, counting pulses of various forms and occurrence intervals, **1257**
Wilson, T. A., with others, a.f.c. of high-power klystrons, **2942**
Wilson, T. G., series magnetic amplifier with inductive loading, **(A)338, 3509**
Winch, G. T., aspects of colour rendering in television, **1818**
Winckel, F., energy spectrum of television image, **234**
Winslade, R., vibration measurements, **790, (D)2400**
Winter, A. J., effect of filament voltage on valve characteristics, **1866**
Winterling, K. H., measurement of resistances $> 10^{12}\ \Omega$, **459**
Witt, H., electrical fluctuation phenomena, **2288**
Witt, R. K., with others, r.f. properties of 16 insulating materials, **1716**
Witten, A. L., and R. E. Henning, wide-band waveguide recording reflectometer, **468**
Woerner, J. J., with others, high-power klystrons, **1213**
Wong, J. Y., radiation of slots in elliptical cylinders, **3482**
Wood, C. B. B., with A. V. Lord, variable-definition camera channel for appraisal of television standards, **1753**
Wood, J. E., with others, temperature variation of magnetization of Ni, **1033**
Wood, R., reliability of subminiature valves with filament cathodes, **3749**
Woods, J., and D. A. Wright, secondary emission from BaO, **895**, changes in, and in thermionic emission during electron bombardment, **2184**
Woodson, H. H., and C. V. Thrower, compensation of magnetic-amplifier servo system, **3114**
Woodward, J. G., and J. B. Halter, lateral mechanical impedance of gramophone pickups, **3181**
Woodward, O. M., Jr, balance measurements on balun transformers, **3663**
—— with G. H. Brown, radiation characteristics of conical and triangular aerials, **1239**
Woodward, P. M., information theory, **3101**
—— with others, electronic band structure of PbS, **2037**
Wooley, M. C., G. T. Kohman and W. McMahon, polyethylene terephthalate as capacitor dielectric, **440**
Woolley, J. C., with others, magnetic viscosity under discontinuous and continuous field variations, **123**
Woonton, G. A., diffraction field of circular aperture, **1294**
Worswick, T., and J. L. Bliss, television camera with optical view-finder, **856**
Wray, A. G., Q-factor measurement, **775**; measurement equipment for f.m. systems, **3664**
Wray, D., unit for superimposing two television pictures, **2174**
Wray, W. J., Jr, RC oscillator, **(D)2604**
—— with L. Packer, Ge photodiodes read computer tapes, **454**
Wright, D. A., conference on microwave physics, Oxford, July 1952, **985**; survey of thermionic emitters, **2832**
—— with J. Woods, secondary emission from BaO, **895**, changes in, and in thermionic emission during electron bombardment, **2184**
Wright, R. W., with others, properties of ferrites at v.h.f., **1312**
Wrigley, W. B., moving poles in nonlinear oscillating systems, **2601**
Wu, Ta-You, with H. E. Moses, dissociation of O_2 in upper atmosphere, **102**

Yaeger, R. E., with others, optical encoder and digit register using transistors, **766, 2373**
Yakovlev, V. A., with A. G. Samoilovich, additional resistance of ferromagnetic metals, **1402**
Yamada, Sigeharu, with others, networks with maximally flat delay, **(D)2259**
Yamaka, E., study of oxide cathodes by X-ray diffraction, **897**
—— and T. Sugita, energy-band structure in Si crystal, **3327**
Yamanaka, S., with Y. Koike, limiting frequency of triode oscillator, **1201**; amplification constants of triodes, **1537**
Yanus, R. I., with V. V. Druzhinin, anisotropy of coercive force in single crystals of Si-Fe alloys, **2704**
Yates, J. G., with K. F. Sander, accurate mapping of e.s. fields in electrolyte tank, **2739**
Yeh, Chai, analysis of single-ended push-pull audio amplifier, **2613, 3251**
Yetter, W. P., with others, synthesis of paralleled 3-terminal RC networks, **3536**
Yonezawa, T., F_2-layer electron-density variations after sunset, **2656**; recombination-coefficient and temperature variations in F_2 layer at night, **2662**; mechanism of electron removal from F_2 layer, **3298**
Yorke, R., with K. R. McLachlan, objective testing of pickups and loudspeakers, **19**
Yoshida, S., and I. Takeda, secondary emission from oxide cathodes, **2836**
—— I. Takeda and H. Arata, dissociation of oxide-coated cathode, **2834**
Yosimoto, H., oscillatory phenomena in hot-cathode discharge tube, **2959, 2960**
Young, A. S., with V. Roberts, PbSe photoconductive cells in infrared spectroscopy, **3142**
Young, J. R., conductivity and thermoelectric power of (BaSr)O and BaO, **896**
Young, J. Z., with F. Roberts, flying-spot microscope, **1759**
—— with others, flying-spot microscope, **3073**
Young, W. R., Jr, mobile radio transmission at 150, 450, 900 and 3700 Mc/s, **823, 1795, 3711**
Youngmark, J. A., loudspeaker baffles and cabinets, **2201**
Yu, Y. P., highly stable variable time-delay circuits, **1261**
Yurkov, V., with others, electrical properties of Sb_2S_3 and Bi_2S_3, **3019**
Yvon, J., theory of ferromagnetism and Heisenberg's model, **1003**

Zaayer, D., 100-kW television output stage, **3742**
Zackay, V. F., and others, fundamentals of glass-to-metal bonding, **2712**
Zadeh, L. A., optimum nonlinear filters, **2598**; theory of nonlinear 2-pole networks, **3220**; analysis of valve and transistor circuits, **3223**; a class of stochastic operators, **3348**; nonlinear multipoles, **3546**
—— and J. R. Ragazzini, optimum filters for detection of signals in noise, **205**
—— with J. R. Ragazzini, analysis of sampled-data control systems, **(A)1801**
Zakhaim, M., impedance transformation of folded dipole, **(D)3200**
Zakheim, J., power amplifier for driving low-power d.c. motor, **687, 2947**
Zavadovskaya, E. K., breakdown strength and mobility of charges in dielectric, **1375**
Zeluff, V., with J. Markus, Electronics for Communications Engineers, **(B)909**
Zemke, H. J., with H. Dippner, reverberation times of Berlin auditoria and sound-recording studios, **3467**
Zenner, R. E., with others, electronic function generator, **451**
Ziegler, H. K., optimum design of permanent magnets, **(A)3039**
van der Ziel, A., noise, shot, in semiconductors, **2040**, in gas discharges, **2185**, accuracy of measurement with square-law detector, **2724**; simple method for measurement of cathode interface impedance, **2839**
—— with W. W. Lindemann, flicker noise caused by interface layer, **1531**
—— with R. H. Mattson, shot noise in Ge filaments, **2035**
Zimmer, E., with H. Hönl, intensity and polarization of e.m. waves diffracted at slit, **3269**
Zingerman, Ya. P., with N. D. Morgulis, investigation of oxide cathode, **1527**
Zinke, O., current and voltage distribution, in cylindrical, ellipsoidal and conical aerials, **2568**, along rotationally symmetrical aerials, **(A)3195**
—— with J. Deutsch, screening of test rooms and instruments from e.m. fields, **3116**
Zirm, R. R., with others, microwave correlator, **1067**
van Zoonen, D., and G. Prast, Jr, properties of Ar-Br-filled counters, **1463**
Zwicker, E., limits of perception of a.m. and f.m. of pure tones, **303**
—— and G. Gässler, suitability of dynamic headphones for measurements on f.m. tones, **312**
—— and W. Kaiser, modulation threshold in audible range, **1892**
—— and W. Spindler, influence of nonlinear distortion on audibility of frequency vibrato, **2870**
Zworykin, V. K., present stage of development of television, **237**
Zyngier, H., with D. Blanc, application of Wilkinson's theory to G-M counters with external cathode, **3389**

World Radio History

SUBJECT INDEX

Abacs, (See also Charts)
for capacitors for zero-temperature-coefficient oscillatory circuits, **954**
for computation of tropospheric refractive index, **1670**
for correction of *Q*-meter errors due to valve-voltmeter loading, **783**
Absorption, (See also Acoustics; Ionosphere)
acoustic, in granular media, **923**
by materials, measurement with directive transmitters and receivers, **12,** reverberation-chamber method of measurement of, **3466,** tube method for measurement of, **925**
by perforated bricks and rock-wool boards for television studios, **3174**
by rubber tank-lining materials, **1569**
in suspensions and emulsions, case of fog in air, **2547**
by tubular and hollow-brick resonators, **310**
acoustic and ultrasonic, in water and aqueous solutions of electrolytes, **2196**
coefficient, acoustic, comparative measurements and test specification, **1570,** as function of angle of incidence, **2548,** measurement of, **2197,** measurement of by long-tube method, **13,** measurement of by reverberation-time method, **3465**
in electron-gas mixture, **2297**
ionospheric, measurement of, **2661**
measurements and theory of, **1679**
observations at Calcutta, **3690**
of pulse signals, automatic measurement of, **1680, 2313, (D)3305**
of short waves, calculation of, **1351,** effect of geomagnetic field on, **1678**
microwave, of electrolytes, **698**
of O_2, line breadths in, **91**
of ND_3, spectrum lines of, **2298**
in polar liquids at 3 kMc/s, standing-wave method of measurement of, **2066**
ultrasonic, in animal tissues and plastics, **1562**
in liquids, and relaxation mechanism, **604**
in mixtures of ethyl alcohol and water, **1222**
of water-borne sound, by resonance-type materials, **308**
Accelerometers, $BaTiO_3$-ceramic, **2399**
Acoustics, (See also Absorption; Broadcasting studios; Impedance; Sound; Ultrasonics)
anechoic chamber at Technische Hochschule, Karlsruhe, **1889**
artificial ears for calibrating telephone receivers, comparison between, **1888**
of auditoria, design problems of, **3175**
of auditorium designed for technical meetings, **610**
bibliography, **1, 910, 1549**
of broadcasting studios, Swansea, Helmholtz resonators for improvement of, **309**
of Cologne broadcasting centre, **3468**
damping of pulsating air bubbles in water, measurement of, **2534**
of halls, analysis of transient effects by means of models, **921**
ceiling treatments in relation to reverberation times, **1896**
diffusion in, **1893**
impedance tube, resolving power of, **2867**
improvements in Vienna church of St. Anthony of Padua, **14**
musical scale, measurement of intervals of, **1887**
musical tone, complex, 3-dimensional representation of, **1219, 3462**
problems at Waldbühne open-air theatre, Berlin, **1573**
properties of building materials, comparative measurements on, **311**
radiation pressure and dispersion, **1565**
reverberation chamber with polycylindrical walls, **922**
reverberation times, of Australian concert halls, **3176**
of 52 Berlin auditoria and sound-recording studios, **3467**
of rooms, boundary conditions for wave equation, **1894**
c.r.o. display for reverberation-time measurements, **307**
effect of wall shape on, **2872**
improvements in absorptive linings, **1567**
measurements of, methods and apparatus for, **606**
and quality of loudspeaker reproduction, **3469**
reverberation-time measurement accuracy with warble tones and with white noise, **1571**
of Royal Festival Hall, London, **2198**
of theatres, sound-delay system for improvement of, **1572**
Acousto-electric effect, 2281
Aerial arrays, broadside, helix, radio-astronomy, at Ohio State University, **3490**
curtain-type, power gain of, **1909**
end-fire, **2901**
optimum design of, **2225**
high-gain, for television broadcasting, **1236**
linear, broadside, slotted-waveguide, with simultaneous odd and even radiation patterns, **40**
for minimum-width single-beam end-fire pattern, **2571**
optimum design of, **1594**
shunt-slot, effects of dimensional errors on performance of, **1592,** factors affecting performance of, **1241**
multiloop, stagger-tuned, for wide-band loran reception, **3207**
radiation pattern of, analogue computer for, **3198**
ring-type, comprising tangential or radial dipoles, **2570**
slotted-waveguide, second-order beams of, **1914**
with symmetrical conductance functions, **2903**
u.h.f., mobile, **2222**
Aerials, (See also Lenses, microwave; Transmission lines; Waveguides)
and aerial arrays, mutual radiation resistance of, **32, (D)627**
Aerials, aircraft, fittings for reduction of precipitation interference, **2895**
'artificial-slot', using high-permeability dielectrics, **1916**
conical and triangular, radiation characteristics of, **1239**
corner-reflector, radiation diagrams of, **2224**
cylindrical, ellipsoidal and conical, current and voltage distribution in, **2568**
solution of Hallén's equation for, **1908**
theory of, **(D)629**
thick, input impedance of, **1235**
dielectric, u.h.f., comparison of disk with other types, **2838**
dielectric-disk, **2572**
dielectric-rod, **325**
longitudinal radiation of, **1244**
polystyrene and lucite, **3479**
dielectric spiral round magnetic rod, **1942**
dipole, cylindrical, gain and back-scattering cross-section of, **(D)2894**
horizontal, in dissipative medium, theory of radiation from, **1587**
with tuned parasitic radiator, **(D)324**
directive, beam shaping for, theory of, **31**
conical-helix, radiation field of, **2899**
using convex waveguide lens, theory of, **3204**
gain of, approximate formulae for, **635**
loop, using ferroxcube rods, **939,** small, radiation resistance of, **2905**
microwave, with plane reflector, analysis for, **1243, 1913,** reflectors for, side-lobe analysis for, **41, (C)2226**
with parabolic reflectors, characteristics in absorbing media, **3206,** with very good matching, **326**
with passive directors, investigation using small-scale models, **2893**
plane reflectors for, **936**
rhombic, coplanar, coaxial, mutual impedance of, **3197,** free-space radiation impedance of, **2898,** receiving, design of, **2223,** receiving, vertical pattern of, **1912**
rotating Adcock, null characteristics of, **2906**
two-mast, medium-wave, design and performance of, **2227**
wide-band, u.s.w., **636**
discone, design of, **3196**
earthing system, radial-conductor, design of, **(C)42**
feeders for, coaxial, developments in, **2210**
losses in, **2211**
flush-mounted, for military aircraft, **634**
folded-dipole, impedance transformation of, **(D)3200**
input impedance of, **3488**
with two or more elements, impedance transformation of, **1234**
Hallén's integral equation for, difficulties with present solutions of, **633**
helical, beam, for citizens' radio, **1593,** performance of, **3489**
high-resolution, for scanning the solar disk, **2573, 3209**
horn, e.m., gain of, **935,** with phase-correcting lenses, **1242**
impedance of, measurement of, **630**
lens, for cm λ, survey of, **3203**
linear, theory of, **3201,** calculation of some definite integrals in, **1238**
loop, for interference elimination in long-wave reception, **35**
for portable receivers, **3481**
receiving, with hollow prolate-spheroidal core, **3491,** with spheroidal ferromagnetic cores, gain of, **1917**
small, measurement of radiation resistance of, **327**
mutual impedance of, simplified calculation of, **3199**
portable 200-ft Al-alloy mast, **3194**
radar, moulded plastic reflector for, **1911**
parabolic, with rotating beam, **1245**
wide-angle-scan, using Schmidt system, **938**
radiation patterns of, c.r.o. display of, **3069**
receiving, cylindrical-wire, back-scattering from, **36**
short, theory of, **628**
rotationally symmetrical, current and voltage distribution along, **(A)3195**
sloping-V, nonresonant, distant field of, **3205**
slot, for f.m. altimeter, **2897**
waveguide-fed, radiating into parallel-plate regions, **1915,** shunt conductance of, **323**
slotted-cylinder, double-slotted, horizontal radiation diagrams of, **2228**
of elliptical cross-section, radiation from, **3482**
straight, theory of, **2220**
thin, carrying harmonic currents, mutual impedance of, **2569**
straight-wire, radiation resistance of, **1588**
switching system for, **33, 933**
television, receiving, **1590,** theory and design of, **1237**
transmitting, B.B.C., **934,** emergency, WJZ-TV, on Empire State Building, **631,** high-power, modern, **632,** suspended feeders at Kirk o' Shotts and Wenvoe, **34, 929,** u.h.f., using slot arrays, **2900**
transmitting, combined, for television and f.m. broadcasting, on Empire State Building, **1589,** for television and u.s.w. broadcasting, **37**
for U.S. Navy 14·5–35-kc/s transmitter, **821**
vertical, double, directional action of, **3208**
ground-reflection phase-error of, **2221**
v.h.f., impedance of, measurement of, **1432**
measurement of radiation patterns of, **3480**
Alloys. See Ferromagnetic materials.
Altimeters, f.m., nonquantized, **3311**
Ammeters, calibration at frequencies > 100 Mc/s, **1075**

World Radio History

Amplification, d.c., limits of, survey of, 2277
of microwave radiation by substances not in thermal equilibrium, 3593
by space-charge waves in electron beam in crossed e.s. and e.m. fields, 278
Amplifiers. (See also Circuits; Television)
a.f., bypass and decoupling circuits for, design of, 2614
constant-current, design of, 1635
differential input stage for, 2616
feedback, Type-PM53, for sound reproducers, 3567
gramophone-pickup, with adjustable response curve, 315
high-power, 2948
input circuits for, 2615
medium-cost, with good performance, 979
negative-feedback tone control for, 64
noise in, 368
pentode output stages of, performance of, 1636
power, for constant-current Class-A2 operation, 2309, 'Maestro', 978
push-pull, single-ended, 3250, single-ended, analysis of, 2613, 3251, using transistors, 3521
a.g.c., using NTC resistors with heater, 1953
cathode-follower, design charts of, 3565
cathode follower circuits as high-impedance input stage for, 367
class-B, avoidance of grid current in, 3249
constant-volume, using cathode-follower circuit, 365, (D)686
d.c., cathode-drift compensation in, (A)2617
coupling of cathode followers in, 3252
high-gain, 172
high-sensitivity, with crystal contact breaker, 787, 2395
high-speed, using moving-coil galvanometer, 1090
with low-pass feedback network, 369
based on magnetic modulator, 72
for measurement of pH, 3683
with negative feedback, 1950
parallel-T, low-drift, wide-band, 982
valve, 981
for voltages down to 10^{-9} V, 2276
dielectric, using ferroelectric capacitor, 1283
mathematical analysis of, 70
differential, for discriminating against push-push signals, (D)1637
distributed, mutual-inductance-coupled, 1284
wide-band, theory of, 2612
for driving low-power d.c. motor, design of, 687, 2947
feedback, design of, 983
h.f., tuned, using transistor tetrode, 677, 1184
l.f., 1–3-c/s, 2950
line and flat-gain, for L3 coaxial-cable system, 3411
line and terminal, for Birmingham/Manchester coaxial cable, design of, 977
'lock-in', using square-wave generator, 2608
magnetic, analysis of, use of flux-charge concept in, 337
balance-detector type, principles and applications of, 3504
basic operating principles of, 332
classification of, 2911
comparison of methods of analysis of, 2910
control of, 3507
dynamic characteristics of, 2579
effective feedback ratio of, 3510
figure of merit of, (A)2580, 2912
half-wave, for servomechanisms, (A)3724
with high input impedance, 336
high-speed, 3512
low-input-power, 333
'Magamp', and industrial applications, 945, 1095
mechanics of, 3503
parallel-connected, with inductive load, analysis of, 1251, with resistive loads, analysis of, (D)944
priority of French publications on, (D)943
with reset control, 2581
rules of similitude for, 334
and saturable reactors, bibliography on, 1887 to mid-1951, 3506
self-balancing potentiometer type, 3511
self-saturated, half-wave, control characteristics of, 3505
self-saturating, steady-state analysis of, 2235
series-connected, idealized, analysis of, 3508, with inductive loading, (A)338, 3509
single-core, as computer elements, 3048
theory of, 2909
transient response of, 2236
transistor-controlled, 3211
with voltage feedback, optimum input-winding resistance of, 3210
3-phase transductor circuits for, 949
60-c/s, application to position-indicating servomechanism, 335
negative-feedback, harmonic distortion in, 2278
using pentode, equivalent-circuit analysis of, 2611
for relaying television signals over coaxial cables, 984
noise/signal ratio of, methods for reduction of, 976
photocell, stable-gain, 692
power, cavity-type, design of, 2949
proportional, reproduction of voltage pulses by, 691
pulse, analysis of response to rectangular wave, 3566
ionization-chamber, background noise in, 1634
use of gas-filled triode in, 2274
push-pull, class-A, distortion in, 2610
integrating, for c.r.o. recording of magnetic flux, 3062
RC, feedback, with electronic tuning, 1638
Amplifiers, *RC*-coupled or direct-coupled output stage of, analysis of, 1286
selective, Wien bridge as frequency-determining element in, 1951
10-c/s–10-kc/s, for null measurements, 1633
superregenerative, microwave, noise in, 1948
transistor, cut-off frequency of, 689
formulae for characteristics of, 1601
noise in, 1288, 2279
transient response of, 3513
variation with frequency of parameter values, 3518
video, amplification and bandwidth of, 69
amplitude and phase distortions in, relations between, 980
effective bandwidth of, 1947
very-wide-band, 2275
wide-band, feedback-pair, 366
for weak photoelectric currents, 329
wide-band, compensated, design of, 1949
voltage ratios of, measurement of in range 1–100 Mc/s, 1735, 2731
Analogies, between acoustic and e.m. phenomena, 911
electrical and mechanical, 988, 989
Analysers, frequency-spectrum, a.f., heterodyne-type, (D)776, heterodyne-type, with mechanical filter, 1227, selective, 2073
for arbitrary function of short duration, 160
mechanical, for pulse series, 3641
harmonic, photomechanical, for transient waveforms, 1439
pulse-amplitude, compensation against grid/cathode capacitance effects in, 941
new design of, 1920
for nuclear research, 639
stability and equality of channel widths in, 2230
Analysis, complex-frequency, using phase principle, 918
dimensional, and rationalization, 3584
frequency, of acoustic phenomena, 1886
spectrum, narrow-band, of p.p.m. signal, 470
Antiferromagnetism, and crystal structure, of CrSb, 3036
properties of CoO and MnO mixtures, 2343
structure deformations in CoO and MnTe, 3035
survey of, 706, 3585
zero-point susceptibility of linear chain, 2633
Astronomy, radio, 92, (See also Cosmic radiation; Solar radiation)
broadside aerial array at Ohio State University, 3490
radio stars, determination of position of, 1329, interferometer measurement of diameter of, 1330, occultation of by solar corona, 98, possible radiation mechanisms of, 1328, scintillation of during aurorae and magnetic storms, 396
Atmosphere, (See also Ionosphere; Troposphere)
correlation of pressure fluctuations with solar activity, 1323
electric-equilibrium layer, height of, 1343
lower, ionic equilibrium of, 719
microwave refractive index of, constants in formula for, 1990, 3287
measurement of variations of, 1085
rapid variations of, 431
slide-rule computation of, 1014
ozone in, density and mean temperature of, annual variation of in Afghanistan, 2979
formation and distribution of, 1015
vertical distribution of, 2649
upper, continuous layer formation in, effect of solar radiation on, 2651
dissociation of O_2 in, 102
effects of solar radiation in, 1321
electrical conductivity of, and diurnal variations of geomagnetic field, 2647
over India, physical properties of, 403
investigations of, and auroral spectroscopy, 1017
photochemical reactions in, 1342, and relation to temperature, 1344
vertical distribution of nitrogen in, 402
between 80- and 250-km height, physical properties of, 3286
Atmospheric electricity, e.s. field at Khartoum during solar eclipse, 25th Feb. 1952, 104
in foggy conditions, 1355
measurement of field by radioactive probe, 1681
potential gradient, 1354
Atmospherics, mean level of, and intelligibility of km-λ radio link, 105
meter for, 'ogiver', 1443
observation stations, list of, 3100
propagation of, theory of, 1108
with very low-frequency components, 2771
Attenuators, cut-off, for waveguide circuits, 1938
magnetically-controlled, u.h.f., 1937, characteristics of, 964
waveguide, inductive, using properties of waveguide below cut-off, 2599
Audiometers, at Technische Hochschule, Stuttgart, 1891
Aurora, in Canada, orientations of, 3307
electron densities in and radio echoes from, 1999
and geomagnetic storms, theory of, 1013
35- and 74-Mc/s pulse echoes during, 2976
location with 10-m radar equipment, 728
radio echoes from, 3308
geometry of, 1357
at 33 Mc/s, long-duration, 2000
and scale-height determinations, 3309
southern zone as defined by homogeneous arcs, 3310
spectroscopy of, and investigations of upper atmosphere, 1017
theory of, 1356, 1358

Barretters, commercial, new, 646

World Radio History

Batteries, accumulator, Ag/Zn, **3728**
Pb-acid, addition agents for negative plates of, **2157,** 'Porvic' separators for, **2156**
dry, Leclanché type, reactivation of, **3117**
recent developments in, **3727**
Beacons. See Navigation aids.
Bolometers, for direct measurement of r.f. power dissipation, **484**
Book notices and reviews, Advanced Antenna Theory, **940**
Antennas, Theory and Practice, **637**
Automatic Feedback Control, **840**
The Design and Analysis of Experiments, **1419**
Electrical Measuring Instruments, Part I, **2398**
Electronics for Communications Engineers, **909**
Filter Design Data for Communication Engineers, **1955, 2280**
Harmonics, Sidebands and Transients in Communication Engineering, as studied by the Fourier and Laplace Analyses, **3719**
Information Theory and its Engineering Applications, **2795**
Landolt-Börnstein Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik, Vol. 3, Astronomie und Geophysik, **1359**
Photoconductivity in the Elements, **2358**
Radio Amateur's Handbook, 30th edn, **2530**
Radio Interference Suppression, **818**
Radio and Radar Technique, **2854**
Radio Research Special Report No. 23, Characteristics of the Ionosphere observed in Great Britain, 1930–1946, **2670**
Radio Research Special Report No. 25, Materials for Radio Purposes, **2359**
Radio Research 1952, **3460**
Radio Spectrum Conservation, **2446**
Television, **578**
Vacuum Tube Oscillators, **2618**
Breakdown, in air, H and He at low pressure in nonuniform fields, **2630**
of gases, secondary processes in, **997**
time lags in, **3262**
h.f., of gases, theory of, **83**
in Ne, **702**
recent information on, **3632**
spark, dependence on humidity and time, **2290**
u.h.f., of gas subjected to crossed electric fields, **3261**
Bridges, a.c., balance approach in, **1434**
d.c., null detector for, design of, **3665**
for dielectric measurements from 100 kc/s to 1 kMc/s, **782**
high-resistance, for measuring conductivity of ground, **3365**
impedance, h.f., with variable ratio arms, **1433**
precision, for frequencies up to 20 Mc/s, **169**
for measurement of admittance parameters of junction transistors at 1 kc/s–1 Mc/s, **3359**
mutual-inductance, for measurements on ferromagnetic cores, **460**
phase, for c.r.o. display of distortion in television apparatus, **2391**
r.f., for measurement of low admittances, use of thermistors in, **1748**
thermistor, for measurement of power at λ 3 cm, **1749, (D)2740, (D)3366**
Wheatstone, for admittance determinations, **(A)3367**
Wien, and applications, **479**
as frequency-determining element in selective amplifiers, **1951**
Broadcasting, B.B.C. equipment for outside broadcasts, **224**
British, future of, **2445**
centre, Cologne, architectural acoustics of, **3468,** supervision of electroacoustical equipment in, **3717,** technical arrangements, **3716**
low-frequency, Pierre Bourdan, Paris, **825**
m.f., influence of ionosphere on, **3096**
studios, auxiliary circuits in, **223**
installations for, and new S.F.R. equipment, **826**
Swiss organization of, **1123**
and television, Radio Canada building, Montreal, **221**
u.s.w., coverage problems of, **2139**
planning of, **2789**
service-area estimation, under conditions of interference, **214,** and system planning for, **213**
——**stations,** on the Hoher Meissner, North Hesse, **222**
medium-wave, s.w. and u.s.w., N.W.D.R., **2148**
small, private, in Germany, transmitters and studio equipment for, **2178**
Wavre-Overijse, transmitting equipment at, **1128**

Cables, coaxial, attenuation of, measurement of in range 1 Mc/s–4 kMc/s, **2072**
characteristic impedance of, unit-step signals for determination of, **2732**
with disk insulator, characteristics of at frequencies > 1 kMc/s, **3183**
with helical-strip insulation, characteristics of at frequencies > 1 kMc/s, **3184**
noise-free, production of, **2878**
pulse deformation in, theory of, **1905**
reflections due to impedance irregularities in, **2730**
r.f., with liquid dielectric, **3472,** measurement of characteristics of, **158**
for television links, factors affecting performance of, **928**
transmission parameters of, **2559**
fault-location by pulse-echo methods, **2727**
with nonuniform characteristic impedance, pulse response of, **2070**
star-quad, without coils, for broadcast programmes, tests on, **1578**
telecommunication, noise measurements on, **3182**
Cables, of Verwaltung für Installationen, Kabel, Apparate, **617**
wide-band, fault location by pulse-echo method, **2728**
Calculating machines. See Computers.
Cameras, (See also Television)
100000 frames/sec, developed at Battelle Memorial Institute, **2056**
Capacitance, of circular annulus, calculation by subarea method, **2302**
of cube, calculation of, **2639**
Capacitors, fixed, developments in, review of, **953**
with high-ϵ dielectric, stray capacitance in, **3217**
metallized-impregnated-paper, high-temperature operation of, **345**
metallized-paper, **344**
mica, l.f. power factor and capacitance of, **1925**
nonlinear, titanate, **2916,** properties and applications of, **2915**
r.f. characteristics of, **(D)51, 2244**
Russian notation for value of, **2927**
vacuum, development of, **52**
for zero-temperature-coefficient oscillatory circuit, abac for, **954**
Carrier-current systems, (See also Telegraphy)
analysis of build-up process in, **1249**
calculation of transients in, **2246**
cable links for, German, **2436**
coaxial-cable, L3, **3409,** amplifiers for, **3411,** equalization and regulation in, **3410,** television terminals for, **3424**
nonlinear filtering and waveform multiplexing for, **670**
power-line, frequency-shift, oscillator and discriminator for, **1482**
noise in, **3705**
transmission factors for, **3704**
telephony, terminal equipment for, **1121**
for Weser-Ems power-supply network, **2435**
Cathode-ray oscillographs, automatic trace brightening for, **3369**
beam intensifier for, **162**
with delayed-trigger timebase circuit, for television waveforms, **1438**
frequency markers and scales for, **1077**
h.v., cold-cathode, **2743**
for interference measurements in aircraft, **2075**
for investigation of transients in heavy-current equipment, **3371**
for television-waveform display, **2745**
time marker, decade, dekatron, **771**
for transistor characteristics, **784, 1437**
trapezoidal distortion in, **2742**
for vector representation of sinusoidal voltages, **3372**
for 1–300-μs pulses with repetition frequencies up to 10^5/sec, **3667**
——**oscilloscopes,** with e.s. deflection, for 100-kV pulses, **3067**
Type GM5660, **3370**
——**tubes,** (See also Counter tubes; Television)
constant-resistance deflection circuits for, **235**
deflection-coil design for, **1834**
flying-spot, new phosphors for, **3608**
life testing of, **1444**
positive- and negative-ion formation in, **2846**
screens of monomolecular thickness for, preparation of, **3761**
storage-type, direct-viewing, bright-trace, **3760**
graphechon, improved, **1539, 2845**
reduction of read-around ratio in, **3353**
single-gun, improved, **1868**
Cathodes, (See also Electron emission)
BaS, properties of, **893**
capillary, metal, **3148**
disk-type, improvements in, **898**
dispenser-type, 'impregnated', **2502**
filament-type, thermal time constant for, **282**
oxide, BaO, activation of, photoconductivity study of, **1529,** dissociation caused by primary electron bombardment, **2834,** luminescence and thermionic emission of, **1712**
BaO and (Ba,Sr)O, conductivity and thermoelectric power of, **896**
(Ba,Sr)O, dependence of thermionic emission on wavelength of illumination of, **284**
BaO-on-W, methods of preparation of, **1189**
base alloys for, double activators in, **3152**
conductivity of, **894,** retarding-potential method for measurement of, **2835**
effect of impurity migrations on, **1858**
effects of oxygen on electrical properties of, **1190, 2503**
experimental investigation of potential gradient in coating of, **1527**
in gas discharges, spectroscopic investigation of, **1188**
interface impedance of, effects in television receivers, **2505,** measurement of, **2839, 3149**
with interface layer, investigations on, **2833**
interpretation of Nijboer's theory for, **2504**
pulsed emission of, decay and recovery of, **285**
review of investigations on, **1528**
secondary electron emission from, **2836**
semiconductor properties and performance of, **286**
and semiconductors, **1859**
thermionic emission and conductivity of, relation between, **3455**
thoria, **2506, 2507, 2508, 2840,** measurements relating to filaments of, **3151**
W-filament, experimental investigation of emission from, **1857**
X-ray diffraction method for study of, **897**
oxidized Ni and W, field emission of electrons from, **1962**
photoemissive, Cs-AgO, changes during heat treatment, **3447**
Cs-Sb, **416,** various, **2824**
relation between sparking phenomena and surface e.s. field, **292**
squirrel-cage-filament, equivalent diameter of, **3153**
wire, temperature distribution at ends of, **283**

World Radio History

Charts, (See also Abacs)
for attenuation of seven commonly used ladder-filter sections, (A)961, 3544
for bandwidth of λ/4 matching sections, 30
for cathode-follower amplifiers, 3565
for coaxial-line probe measurements, 458
for design of planar triodes, 2514
for skin effect in conducting materials, 435
for solution of sky-wave problems, 1469
for use in high-Q measurement, 464
for winding data of dust-cored coils, 647
Chronographs, recurrent sweep, 3068
Circle diagrams, for certain types of network, 43
for input admittance of grounded-grid disk-seal triode, 3564
Circuit diagrams, standardized layout for, 3492
utility factor in, 63, 671
——**theory,** (See also Networks)
Ohm's law for build-up phenomena, 638
pass band, general definition of, 3534
relation between width of and transient distortion, 3539
resonance characteristics by conformal mapping, 53
Circuits, (See also Networks)
a.f.c., lock-in performance of, 1280
anode-follower, derivatives of, 658
antiresonant, electronic, 2591
and assemblies, etched, plug-in, for computers, 2263
cathode-follower, with capacitive load, (D)1285
as high-impedance amplifier input stage, 367
RC, 662
theory and design of, 3247
combining, for connecting transmitters to common aerial, 870
correction, design of, 1450
counter, decade, gated, 1256
for random pulses, 1257
coupled, natural frequencies of, equations for, 1276
coupled inductively, double resonance in secondary of, 1620
equivalent, for three-pole and multipole networks, 2247
feedback, relation between closed-loop transient response and open-loop frequency response of, 3231
use of signal-flow graphs for analysing, 3531
using ferrite magnetostrictive resonators, 2229
ferroresonant, automodulation in, 1270
flip-flop, Eccles-Jordan, design of, 952
for l.v. operation, design of, 1602
triode, design for long-term stability of, 3558
impulse-governed-oscillator (I.G.O.), Type-E8OT beam-deflection valve in, 2817
LRC, with nonsinusoidal voltage, power in, 1259
multivibrator, bistable, design of, 1946
negative-resistance, transistor, analysis of, 641
nonlinear, effects in, and applications of, 2273
series, subharmonics in, 2929
oscillatory, amplitude stability in, 3242
damped, field quantization applied to, 3243
LC, temperature compensation of, 2603
parallel-tuned, periodically switched to d.c. source, analysis of, 65
relation between susceptance slope and selectivity, 2928
response of, to linear-frequency-sweep voltage, (D)2930, to 'ramp' voltage, 2265
including temperature-dependent elements, 68
with variable inductance, transient phenomena in, 3551
3-dimensional locus curves for, 2266
including overdriven valves, graphical analysis for, 356
phase-delay, wide-band, waveguide, 3192
printed, production of, auto-sembly technique for, 355, 3548, plating method for, 354, Technograph etching system for, 353
for transistors, 674
unit assemblies for television, 352
printed and potted, 2926
using quartz-crystal, as f.m. oscillator and discriminator, 1277
RC, with voltage gain, 663
resonant, *RLC*, action of train of pulse signals on, 3241, in series, response to e.m.f. whose frequency is a linear function of time, 1941
spontaneous voltage fluctuations in, 676
response to f.m. signal, and analogy with a.m., 3246
scaler, ferromagnetic, 1255
square-law, for use with graphic recorder, 346
switching, high-speed, bistable, 648
transistor, 652, 3515, graphical analysis of, 653
time-delay, variable, highly stable, 1261
transconductance-bridge, for frequency elimination, 59
transistor, and applications, 3213
complementary-symmetry, 3519
matrix representation of, 642
theory of, 3520
with transformers, 1287
trigger, for cold-cathode counter tubes, 49
transistor, 651, design of, 2914
using Type-A transistors, 3516
valve, without anode supplies, 685
applications of tensor theory to, 659
grounded-electrode, analysis of three types of, 1632
novel, 2600
triode, transformations of, 3529
valve and transistor, simplified analysis of, 3223
Classification, decimal, universal, explanation of principles of, 2520
Clocks, atomic, and frequency stabilization, (D)1422
quartz, of Greenwich time service, 3354
Clutches, moving-coil-actuated, 1094
Coders, feedback, for analogue to digital conversion, 3414
Coils, choke, for airborne power supplies, design of, 1924
for communication equipment, with ferrite cores, design of, 1923
dust-cored, charts for winding data of, 647
with ferrite cores, copper eddy-current losses in, 3526
helical, in dielectric supports, attenuation of, 1523
single-layer, calculation of parameters of, 1922
toroidal, powder-core, moisture aging of, 2355
Communication, theory of, analytical signals with limited spectra, 2137
application, to telecommunications and radar, 1792, to tele-control and measurements, 1481
autocorrelation from ergodic hypothesis, 535, calculation for tele-type signals, 537
comparison of channel capacity of a.m. and ph.m. systems, 2786
concept of entropy in, 536
correlation *v.* linear transforms, 1477, (D)3701
'ideal coding' *v.* 'redundancy', 1478
introduction to, 3101
limits on information content of e.m. signal, 2135
prediction of nonstationary stochastic processes, 445
research on, problems and methods of, 1479
statistical, introduction to, 819
statistical equivalent of optimum transducers, 3700
——**equipment,** (See also under individual subjects)
beam-radio, dm-wave, FREDA I, 2160, Swiss developments in production of, 1548
f.m., transportable, microwave, for military purposes, 1127
microwave, multiplex, Types FR and FJ, 3107
multiplex, time-division, 212
and navigation aids, aboard merchant ships and fishing vessels, 3418
24-channel, p.p.m., input circuit and i.f. amplifier of, 1483
——**systems,** (See also Carrier-current systems; Radio links; Radiotelegraphy; Radiotelephony; Relay systems; Telegraphy; Telephony)
air/ground, radio-link system, 3715
'ambiguous-index', 2433
for civil aviation, 1024, 3419
installations at French overseas aerodromes, 3419
on German railways, 210
harbour radio, v.h.f., German, 1487
on Indian railways, 1122
linear, optimum transfer characteristics of transmitter and receiver for, 2136
mobile, channel spacing for, choice of, 3714
f.m., multi-station, for Ayrshire police, 1129
frequency-band economy in, 1797, 3713
m-λ, bibliography on, 3407
R/T service in Belgium, 3718
split-channel system for, at 50 Mc/s, field test of, 3709, at 50 Mc/s, operational experience of, 3710, at 152–174-Mc/s, 3102, 3706, at 156·3 Mc/s, tests in Syracuse, 3707
20-kc/s split-channel system for, at 160 Mc/s, commercial experience with, 3708
tests on frequency bands for, 823, 1795, 3711
multiplex, frequency-division, distortion reduction in, 2788
subcarrier bandwidth and response speed of, 3103
time-division, 1793
p.c.m., 12-channel, experimental, 1125
p.p.m., directional, performance figures for, 2146
radio services of West German Post Office, 539
in Swiss army, development of, 1118
telephony and telegraphy, between Turkey and the West, 2143
v.h.f., multiplex, in Nyasaland, 1485
review of, 547
Components, for airborne electronic equipment, reliability of, 1939
and materials, for reliable equipment, 2261
microstrip, manufacture of, 623, 1269
new, on French market, 2529
nonlinear, in h.f. and l.f. technology, 645
tests under tropical conditions, 1713
Computers, (See also Correlators)
analogue, for arc tan ω, 3642
continuously variable voltage source for, 1056
for correlation functions, 161, 453, 3047
differential analysers, C.S.I.R.O., 1049, universal unit for, 146
diode-bridge limiter for, 2367
effect of regenerative loops in, 3647
electronic, 5-channel, 2366
electronic function generator for, 451
elements of, 3043
for Fourier analysis of seismic transients, 2719
for geophysical data, 2718
high-speed, for product integrals, 2058
for hydraulic remote-position-control servomechanism, 1054
linear-to-logarithmic voltage converter for, 3042
for magnetic electron lenses, 2722
for mechanical systems, diode limiters in, 448
for mine ventilation networks, 3349
MONECA, for motor-performance calculations, 765
multiplier circuit for, high-accuracy, 151, using modulated pulses, 1417
photoformer design and performance, 452
for radiation pattern of aerial array, 3198

World Radio History

Computers, analogue, relative merits of a.c. and d.c. as signal source in, **2717**
resistor-network, **2059,** for biharmonic functions, **1727,** for waveguide and cavity-resonator problems, **(A)150**
for servomechanism design, **1055**
for solving algebraic equations, **3044**
for solving differential equations, use of extrapolation techniques with, **1416**
for solving nonlinear differential equations, **2372**
torque-type, **2364**
for use in loudspeaker design, **3050**
analogue and digital, characteristics of basic units for, **2363**
interconversion of data for measurement and control systems, **2365**
digital, automatic programme planning for, **147**
built on sub-unit principle, '401' model, **2368**
chess-playing, basic features of programme for, **3046**
C.S.I.R.O. Mark 1, **1050,** magnetic-drum auxiliary storage system for, **3646**
DINA, for Laplace, Poisson, diffusion and wave equations, **3045**
EDVAC, **2060,** input-output system of, **2371**
electronic, logical symbols for circuit elements of, **1052,** physical realization of, **447**
ERA 1101, design features of, **1414**
Ferranti, photocell input-tape reader for, **1418**
ferroelectric materials as storage elements for, **1053, 3049**
'floating address' system for, **1722**
Göttingen G1 and G2 models, **1723**
information transfer from punched cards to binary system, **3644**
magnetic-disk pulse-storage device for, **494**
magnetic recording heads for, design of, **768**
magnetic storage devices for, **3351,** magnetic-shift register, **3352,** multistable, **449,** rapid-access, **1724**
at Manchester University, multiplication process in, **1051**
micro-programming and design of control circuits in, **2716**
number-display unit for, high-speed, **2370**
Numerograph recorder for, **1726**
optical encoder and digit register for, transistor-type, **766, 2373**
parallel, gating method for, **2374**
plug-in etched-circuit units for, **2263**
programme for 'learning' by, **1415**
programme-controlled, present development in Germany, **1725**
regenerative amplifier for, **769**
serial adders for a variable radix of notation, **3645**
storage systems in, bibliography on, **3648,** c.r.-tube, Scotch-plaid raster for, **3649,** matrix-type, **1728**
transistor shift register and serial adder for, **767**
transistor units for, **1729**
use in control systems, **3075**
use of ferrites in, **2061**
use of Ge photodiodes for reading tape input in, **454**
use of single-core magnetic amplifiers in, **3048**
Whirlwind I, **446**
digital-to-analogue converter for, **148, 450**
integrator for products, **149**
multiplier for, time-division, stabilized, **3643**
punched-card-controlled, for aircraft navigation, **2674**
statistical tabulator for l.v. randomly varying quantities, **2369**
Conduction, electronic, in crystals, sign of e/m for, **1301**
mean free path of electrons in Bi, **996**
in metals with positive Hall effects, e/m ratio for carriers in, **700, 1300**
Conductivity, electrical, of MgO single crystals, measurements of, **2327**
ionic, in solids, pre-exponential factors in formulae for, **3578**
of ionized gases, **2291**
of water, ethyl alcohol and soil, at λ8·6 mm, measurement of, **3655**
Conductors, of arbitrary cross-section, h.f. resistance of, calculation of, **3188**
galvanomagnetic effects in, review of, **1974**
round, a.c. resistance and reactance of, **1918**
Conferences and conventions, application of radar in meteorology, Montreal, September 1952, **1361;** applications of communication theory, London, September 1952, **1480, 2432, 3601, 3702;** cathode electronics, Kiev 1951, **892;** C.C.I.F., 16th plenary assembly of, Florence 1951, **533, 1120;** C.C.I.R., Stockholm 1952, European broadcasting, **211, 534. 1799,** u.s.w., **1488;** electrical engineering measurement technique, Delft, May 1952, **154;** Electrical Engineering U.D.C. committee, Copenhagen 1952, **2191;** electron microscopy, Bristol, September 1952, **1771,** Tübingen 1952, **190;** electron optics symposium, London, May 1953, **3681;** electronic instruments symposium, September 1952, **1217;** h.f. electrical measurements, Washington, January 1953, **3651;** I.E.E., British contribution to television, 1952, **243,** symposium on insulating materials, March 1953, **2351;** information theory, London 1950, full report, **2134;** international electroacoustics congress, June 1953, in Netherlands, **2855;** I.R.E., Australia, 1952, **598,** National Convention, New York, March 1953, **1873;** magnetism, Washington, September 1952, **2292;** microwave physics, Oxford, July 1952, **985;** powder metallurgy, Austria, June 1952, **1412;** radio, international, 1946–1951, frequency-spectrum work of, **1124;** radio noise symposium, **693;** semiconductors, Kiev 1950, papers at, **419;** U.E.R., magnetic sound recording, Hamburg, November 1952, **1577;** U.R.S.I., 10th general assembly of, Sydney 1952, **2521, 2522**
Connectors, plug-and-socket, multiconductor, printed, **2239**
Contact potential, calculation of, **2286, 2287**
measurement of, comparison of methods for, **993**
variable-capacitor method for, **3259**
of semiconductors, experimental investigation of, **1698**
——resistance, of two granular metal films, **3258**
Contacts, initiation of discharges at, **3579**
metal, at low voltages, in adverse environments, **3496**
noise in due to passage of d.c., **3498**
Pt, effect of circuit inductance on fine transfer between, **3495**
for vibratory converters, long-life, **3497**
Control, (See also Electronic applications; Frequency control; Servomechanisms; Telecontrol)
electronic, of glass-grinding machines, **3379**
of high-power industrial equipment, using magnetic amplifiers, **176**
——systems, automatic, design criteria for, **2450**
design of, **1760**
feedback, compensation of, **1135**
nonlinear, stabilization of, **1761**
synthesis of, **3720**
sampled-data, analysis of, **(A)1801**
comparison of sampling with a.m. for, **3722**
with time delay, theory of, **2087**
Converters, (See also Frequency converters; Image converters)
d.c./a.c., gas-tube, for low direct voltages, **2456**
induction galvanometer, **3666**
utilizing valve space-charge capacitance, **1600**
vibrating-capacitor, and application to contact-potential measurement, **475**
negative-impedance, using transistors, **2582**
Cores, with air gaps, alternating-field losses in, **1721**
ferrite, high-μ, complex permeability of, **1705,** measurements on, **1032**
ferroxcube, rod and tube, losses in, **3636**
gapless, for magnetic amplifiers, production testing of, **471**
powder, for military communication equipment, **436**
toroidal, with one or two air gaps, magnetization of, **2584**
Correlation methods, for detection of weak signals, **2124**
determination of output spectra of detectors by, **3699**
Correlators, analogue, 5-channel, **2720**
filtering of clipped signal plus noise in, **532**
for microwave signals, **1067**
thermistor-bridge, **3350**
Cosmic radiation, r.f., (See also Astronomy, radio; Solar radiation)
from galactic hydrogen, at 1·42 kMc/s, **96, 718**
from galaxy, and cosmic rays, possible relation between, **97**
effect of H II regions on, **3278**
origin of, **1331**
use for investigation of ionospheric irregularities, **722**
positions of six discrete sources of, **717**
from stars, at 81·5 Mc/s, ionospheric refraction of, **407**
from supernova (A.D.1572), at 158·5 Mc/s, **95**
Counter tubes, (See also Valves)
cold-cathode, decade, Type-6167, **1867**
gas-filled, principles and operation of, **3763**
rotating-beam, decade, **2515**
Counters, with Ar and methylene-halide filling, **1461**
binary, reversible, transistor, **650, 2243**
coincidence, using Type-6BN6 gated-beam valves, **512**
G-M, Ar- or (Ar-CO_2)-filled, discharge mechanism in, **1462**
(Ar-Br)-filled, properties of, **1463**
battery-operated, **3682**
effect of dead time of, **1464**
end effects in, **2411**
with external cathode, application of Wilkinson's theory to, **3389,** C_2H_4 and C_2H_4O as quenching agents in, **2105,** with pure methyl-alcohol filling, **3087**
limitation of discharge in, **3390,** circuit for, **73**
l.v., gas-filled, **3085**
production range of, **797**
self-quenching, with external cathode, characteristics of, **3089,** with external cathode, photosensitivity of, **3088,** factors affecting life of, **2104,** functioning of, **3086**
space-charge sheath in, **798**
for X-ray interference measurements, **799**
Maze-type, with external cathode, construction of, and characteristics in range 0–50°C, **2106**
pulse, bibliography on, **649**
scale-of-ten, using 4 double triodes, **2242**
scale-of-two circuits, coupling of, **950**
scintillation, discrimination against noise in, **191**
resolution of, improvement of, **2107**
self-quenching, parallel-plate, vapour-filled, **796**
ternary, high-speed, **50**
Couplers, aerial, Π-network, design of, **(D)2588**
bidirectional, resistive T networks as, **2592**
directional, for s.w. reflection measurements, **477**
Transvar, **2931**
wide-band, for power-line carrier equipment, **359**
Coupling coefficient, of i.f. transformers, measurement of, **3658**
of toroidal coils, simple method of, **3554**
Crystals, (See also Piezoelectric crystals; Quartz crystals)
CdS, single, method of growing, **135**
electronic states under strong applied fields, **736**
single, ZnO with excess Zn, optical and electrical properties of, **3628**
synthetic, recent applications of, **1046**
Current, distribution in cylinders, **1650**
electric and diffusion, relation between, application to E-layer displacements, **385**

World Radio History

Demodulation, magnetic, **3400**
Detection, linear, of a.m. signals, **208**
of randomly modulated carrier, for pulsed radar, statistical theory of, **3602**
synchronous, of a.m. signals, **528**
of weak signals, by correlation methods, **2124**
Detectors, crystal, Si, **2190**
Si and Ge, conductivity of and flicker effect in, **2189,** flicker effect in, **1047**
diode, efficiency and damping of, **1195, 2129**
ionized gas, for microwaves, **530**
linear and square-law, correlation method of determining output spectra of, **3699**
linear, square-law, and 3/2-power-law, signal/noise characteristics of, **529**
Dictionaries, radio, English-French, A–C, **597**
Dielectric constant, of absorptive liquids at cm λ, interferometer measurement of, **461**
coaxial-line measurement equipment for range 100–300 Mc/s, **481**
and complex permeability, measurement of at u.h.f., **2381,** optical method for, **995**
of fluids, measurement at cm λ using coaxial-cylinder method, **1734**
of gases, at cm λ, **1063**
of heterogeneous mixtures, theory of, **1693**
of ice, anisotropy of, **2027**
of Rochelle salt, at 3 kMc/s, cavity-resonator method of measurement of, **2729**
of solids and liquids, measurement of, at cm λ, **2067,** results at 9·5 kMc/s, **2068,** using waveguide methods, theory of, **2069**
of uniaxal crystals, measurement by cavity-resonator method, **2382**
of water, ethyl alcohol and soil, at λ 8·6 mm, measurement of, **3655**
of water films and composite mica/water blocks, **1040**
of water in wet clay, **99**
——**loss** angle, bridge method for measurement of, **781**
in solid insulating materials, representation of, **2354**
——**properties,** (See also Insulating materials)
of dipolar materials, frequency dependence of, **1647**
measurement of, by bridge methods, at 80 c/s–40 Mc/s, **3057**
of polar liquids at u.h.f., **698**
of polyethylene terephthalate (mylar), **440**
of poor insulators, double-resonant-circuit method of measuring, **2380**
of solids, u.h.f. measurement of, **3656**
theories of, **1692**
of water and of human blood, at u.h.f., **139**
of zirconates, stannates and titanates of bivalent metals, **433**
Dielectrics. See Insulating materials.
——**, artificial,** including arrays of conducting elements, properties of, **2902**
made of conductive particles embedded in wax, **2326**
isotropic, theory and properties of, **(D)113**
for microwave lenses, refractive index of, **3652**
variational methods for, **2325**
Diffraction, (See also Wave propagation, e.m.)
acoustic, by aperture in plane screen, **1881**
by circular apertures, **1557**
by small circular aperture, **3170**
of cm waves, application of Kirchhoff's theory to calculation of, **1296**
by circular aperture, of diameter < λ, **1666,** of diameter > λ, **1667**
by metal cylinder, theory of, **1665**
by diaphragms with slits, in rectangular waveguides, **1583**
by diaphragms in waveguides, **625**
of e.m. or acoustic pulse, by 90° wedge, **986**
of e.m. waves, by aperture in conducting screen, **1293**
by apertures in plane conducting screens, **710**
by circular aperture, **1294**
by conducting circular disk and by circular aperture in conducting plane screen, **3270**
double-approximation method of analysis of, **1295**
by an edge and by a corner, **711**
by half-plane, **88**
by slit, **3269,** exact solution for, **1971**
by thick semi-infinite perfectly conducting plate, **2295**
three-dimensional problem of, **1972**
of e.m. waves from dipole, by half-plane, **2296**
grating, microwave, experiment with, **1246**
plane, e.m. properties of, **3588**
of plane e.m. waves, by circular aperture, **2625**
of plane sound wave, by paraboloid of revolution, **3169**
rigorous theory of, uniqueness of solutions in, **373**
simplifying technique in solution of problems of, **374**
of sound pulse, by nonrigid semi-infinite plane screen, **602**
by oscillatory long strip, **601**
theory of, inconsistency in, **696**
of v.h.f. waves by hills, **3091**
Direction finders, c.r.o. and goniometer types, comparison of, **1367**
polarization errors of, classification of, **(D)2008**
——**finding,** effect of buried cables on accuracy of, **2997**
and ionospheric anisotropy, **2318**
m.f., in aircraft, origin of errors in, **414**
Discharge, (See also Breakdown)
between coaxial cylindrical electrodes in transverse magnetic field, **1655**
corona, suppression methods for, **1306**
currents, self-maintained, control by cathode illumination, **3264**
gas, British Association discussion on, **701**
effect of superposed r.f. field on, **3263**
at electrical contacts, initiation of, **3579**
Discharge, gas, h.f., characteristics and mechanism of, **1961,** electrodeless, in magnetic field, resonance in, **85,** measurement of admittance and electron density of, **463,** between plane plates, low running potential of, **703**
low-pressure, reliability of probe measurements in, **381**
microwave determination of electron density in, **380**
shot noise in, **2185**
at single electrode, at 31·7 Mc/s, **1307**
Hg-vapour, absorption and reflection of microwaves by, **1656**
microwave admittance of, **1654**
in magnetic fields, investigations of, **1653**
mechanism of, **1652**
spark, in N_2, time lag of field breakdown in, **1308**
between positive point and plane in compressed air, **3265**
in transverse magnetic field, theory of, **84**
——**tubes,** (See also Valves)
cold-cathode, switching applications of, **288**
Type-2313, for switching systems, **538**
corona, for voltage stabilization, **1136, (D)2803**
glow, voltage-regulator, characteristics of, **(D)267**
hot-cathode, oscillatory phenomena in, **2959, 2960**
Discriminators, frequency, for f.m. reception and a.f.c., **684**
using quartz-crystal circuit, **1277**
u.h.f., frequency-stabilized, **2386**
Distance measurement, by echoes, optimum signal characteristics for, **411**
Distortion, amplitude and phase, effect on limited-spectrum signals, **1177**
in video amplifiers, relations between, **980**
in anode-modulated transmitters, **262**
in class-A push-pull amplifiers, **2610**
due to curvature of valve characteristics, **1854**
'difference-diagram' method of diagnosis of, **2383**
in f.m. reflex klystrons, **1545**
of f.m. signals in tuned interstages, evaluation of, **3550**
in f.m. systems, calculation of, **2141**
due to perfect reactance valve, **3104**
due to small loss and phase variations, **1484**
in frequency-division multiplex systems, reduction of, **2788**
group-delay, in transmission system, measurement of, **1076**
harmonic, in f.m. or ph.m., **1282**
meter for, theory and construction of, **1078**
in negative-feedback amplifiers, **2278, (D)3253, (D)3568**
intermodulation, in multichannel radio systems, **1796**
significance and measurement of, **1737**
measurement, double-tone and intermodulation methods of, comparison of, **163**
meter, rectifier-type, direct-reading, 0·5–30 %, **167**
modulation, in television reception, **260**
due to multipath transmission, in f.m. u.s.w. R/T beam link, **218**
nonlinear, in broadcasting-studio a.f. equipment, measurement of, **2735**
comparison of measurement methods, **2734**
in gramophone reproduction, measurement of, **2736**
intermodulation methods of measurement of, **2737,** rigorous basis of, **3059**
of progressive sound waves, **1553**
in transmission of musical intervals, perception of, **304**
in teleprinter signals, definition and c.r.o. measurement of, **3408**

Earth, rate of rotation of, changes of since 1820, **1332**
Electrets, 74
mathematical theory of, **3257**
plastic, experimental investigation of, **2025, 3323**
Electric field, above and below infinite corrugated sheet, **2965**
2-dimensional, correlative property of, **3573**
Electrical quantities, sinusoidally varying, vector representation of, **1919**
Electrodynamics, nonlinear, theory of, **1969**
unified gravitational-field theory of, modification of, **1291**
Electroluminescence, explanation in terms of glow discharge, **1644**
refutation of, **3255**
field strength and temperature of $ZnS_{0.8}Se_{0.2}$:Cu powders in thermoplastic matrix, **3575, 3576**
initial rise of brightness under action of alternating field, **2282**
measurements on lamps and studies of phosphors, **2956**
new light source, **3256**
of ZnS-Cu phosphor, **2283**
Electrolyte tank, accurate mapping of e.s. fields in, **2739**
Electromagnetic field, in conducting medium, of electric dipole, **2109**
of magnetic dipole, **39, 2413, 3202**
impulse, **38, (D)1591**
in plane of circular aperture, for incident spherical waves, **1667**
of rotating uniformly magnetized sphere, **1334**
——**theory,** circulation in flow of electricity, and Dirac's new variables, **1645**
current distribution in disk rotating in magnetic field, **1313**
general relativistic equations for material medium, **1956**
Maxwell's equations, general solutions of, **2294**
Poisson-Kelvin hypothesis and theory of dielectrics, **994**
simplified form of relativistic e.m. equations, **707**
Electrometers, logarithmic-scale, 10-V–1-kV, **3364**
Electron beam, entering coaxial magnetic field, characteristics of, **2638**
deflection systems for, and their aberrations, **2842**
focused, electron-charge spreading of, **2962**
focusing of, optimum space-charge-controlled, **901**
in rotating magnetic fields, nonoptical theory of, **3580**
high-energy, radiation from, **3582**
low-noise, **1183**

World Radio History

Electron beam, magnetic-field focusing of, 175
modulated, measurement equipment for, 263
reflected, space-charge spread of, 2961
space-charge-wave propagation in, 268, 3450
influence of Lorentz force on, 2182
in static e.m. fields, imaging properties of, 1657
velocity distribution in, change of, 2493
——emission, (See also Cathodes; Photoelectric emission)
field-type, from CdS and CdSe, 1391
from surface films, 3287
and work function, of crystal surfaces, 1963
secondary, from Ag and Cu films for primary-electron energies < 10 eV, 1658
from BaO, 895
from cold-worked metals, 1390
determination of origin of electrons, 2336
from dielectrics under single-pulse conditions, 3008
field-dependent, mechanism of, 998
measurement of, errors in, 3581
from metals, after irradiation, 3266, due to Li^+ ions, 384, 2631
from Ni, angular distribution of, 584
theory of, 705
thermionic, correction to Schottky's equation, 1861
energy distribution of electrons in, 2963
flicker effect in, temperature dependence of, 3150
pulsed, electron-velocity distribution in, 2837
from various materials, survey of, 2832
work function of, graphs for calculation of, 3583
thermionic and secondary, from BaO during electron bombardment, 2184
thermionic constants, of metals of the first transition group, 1392
of monovalent metals, 2700
from valve grids, and its elimination, 899
——gas, magnetic properties of, and number theory, 991, 992
——guns, single-velocity, noise analysis of, 1848
——lenses, astigmatism of, 2097
e.m., sector-shaped, angular aberrations in, 3680
e.s., aperture, focal properties and spherical-aberration constants of, 188
cylindrical, with three slits, field of, 2094
determination of electron trajectory by successive differentiations, 2096
electron-optical properties of, 795
for focusing high-energy particles, 2409
for focusing very-high-energy particles, 1769
immersion objective, low-voltage, experimental investigation of, 2410, with plane electrodes, 1458, 1770, resolving power of, 186, 187
paraxial trajectories in, 510
potential distribution in, 3383
single, permitting rigorous calculation, 2095
spherical aberration of, calculation of, 1100, measurement of, 1459
with thick electrodes, axial potential distribution of, 1102
grid-type, spherical aberration of, 1101
magnetic, asymmetry of, 2098
axial field of, approximate formula for, 2099, electrodynamic measurement of, 1743, measurement of derivatives of, 185
with axial field γ/z^n, 189
effect of pole-piece saturation in, 3386
remanence in soft-iron circuits of, 2102
and quadripole networks, analogy between, 2760
with radially decreasing magnetic field and cylindrical electric field, focusing properties of, 1460
——microscopes, device for selecting specimen detail for observation, 3080
direct measurement of images in, 2759
emission-type, image aberrations due to cathode irregularities of, 3081
surface images obtained with electrons due to bombardment by ions, 2757, 3388
e.s., with intermediate accelerator, h.f. h.v. equipment for, 2103
for laboratory, construction details of, 2101
magnetic circuit in lenses for, 3385
R.C.A. Type E.M.U., objective-aperture centering and interchanging device for, 2758
reflection-type, 1457
scanning-type, 1768
improved, for opaque specimens, 3382
small, design of, 2756
——microscopy, field-emitter fabrication and application, 3082
——motion, in Coulomb electric and uniform magnetic fields, 1648
in electric and magnetic field, analysis of, 76
in field of uniformly wound toroid, 383
——multipliers, (See also Photocells)
with BeCu plates, activation of, 1517
development of, 3139
theory of and experiments on, 289
——optics, double focusing of charged particles with wedge-shaped magnetic field, 1456
ideally focused systems, space-charge requirements in, 3384
spherically corrected systems, adjustment of, 2100
third-order aberrations of centred systems, calculation of, 3083
——trajectories, automatic tracer for, 476
calculations of, 511
determination by successive integrations, 1767
in e.m. and e.s. fields, calculation of, 77
rubber-membrane model for study of, 3756

Electron tubes, (See also individual types)
for industry and research, classification of, 587
Electron-ion streams, propagation in, 1316
Electronic applications, (See also Control; Heating; Photocells, applications of)
acoustic firing-error indicator, 192; aircraft-vibration research, 491; cable-diameter measurement, 791; camera-shutter testing, 2750; contour recording and reproduction using magnetic tape, 1449; control of soldering machines, 193; electronic balance, rapid, 3685; food sterilization by h.v. electron beam, 505; industrial uses of 'Magamps', 945, 1095; inspection of wire ropes while in service, 503; magnetic method for testing winding ropes, 3378; measurement of pH, 3683; measurement of spray particles, 3684; measurement of velocity of explosion-wave fronts, 2086; nonquantized f.m. altimeter, 3311; prevention of drill breakage, 2088; resistance-welding control, 502; speed-sensing relay, 499; tachometer, 2747; in textile industry, 177, 504; viscometer with servomechanism, 3673
Electronic engineering, sources of information on, 2192
Electrons, atomic mass of, and Rydberg constant, 697
charge on, determination from shot-noise measurements, 1959
deflection by charged filament, 1299
Dirac's equation of, application of Schwinger's variational principle to, 2626
Dirac's new theory of, angular momentum in, 1297
discussion of, 990
energy momentum tensor in, 1298
fast, charge on, measurement of, 2957, 2958
kinetic energy of, influence of magnetic impulses on, 2300
mobility in strong e.s. fields, 1302
photo- and exo-, use for surface investigations, 2301
velocity distribution after passage through matter, 704
Energy flow, calculation by means of Laplace transform, 955
Equalizers, attenuation, performance of, 2594
variable, for broadcast programme circuits on trunk lines, 820
Exhibitions, A.P.A.E and B.S.R.A., London 1953, a.f. equipment at, 2531; Audio Fair, 1952, 1218; British Instrument Industries, July 1953, 3162; components, Paris 1953, 2262, 3547; Paris Fair, 1953, radio and television receivers at, 3398; Physical Society, 1953, 2523, 2524; R.E.C.M.F., April 1953, 1618, 2524; S.B.A.C., Farnborough 1952, 226, 1216; Scientific Instrument Manufacturers' Association, London 1952, 1547; Technical Fair, Hanover 1952, 166, 178, 299; Television Society, December 1951, 232; 2nd Television Salon, Paris, October 1952, 845; 6th R.S.G.B. amateur-radio, 1215; 19th National Radio, London 1952, 300, 301; 20th National Radio, London 1953, 3163, 3765
Experimental curves, successive differentiation of, and method of smoothing, 2619
——results, representation by equations, 370, 371

Facsimile, high-speed system, direct-scanning, (A)841, 3730
Philips, 2460
improvements in Italian equipment for, 1492
new equipment for, 557
review of development of, 558
transmitter-receiver using subcarrier f.m., 559
weather-map transmissions from Washington, Port Lyautey, Balboa and Frankfort, 1138
Faraday effect, in conductors and semiconductors, 2299
in ferrites at u.h.f., and microwave gyrator, 2922
for guided microwaves, (C)1232, 2889
measurement of, 2890
for microwaves, in nonsaturated ferromagnetic materials, 1709
Feedback, (See also individual equipment)
frequency-dependent, 3549
systems, conditionally stable, design of, 2453
Ferroelectric materials, $BaTiO_3$, dielectric properties in stationary fields, 3011
domain properties of, 759
effect of polarizing field on properties of, 112
$BaTiO_3$ ceramics, effect of composition on properties, 3010
h.f. hysteresis loops of, 3012, 3013
with maintained bias voltage, electromechanical response and dielectric loss of, 3168
$BaTiO_3$ and $BaTiO_3$-$PbTiO_3$ ceramic, measurements on, 1694
$BaTiO_3$ single crystals, dielectric properties of, 3009
statistical model of, 1043
Cd and Pb niobates, crystal structure of, 1374, 2324
ceramics, variation with time of dielectric constant, 2026
KH_2PO_4, properties below Curie point of, 2047
X-ray analysis of transition in, 2048
$PbTiO_3$ single crystals, dielectric properties of, 1410
properties and applications of, 1373
for radio applications, properties of, 3635
Rochelle salt, effect of electric field on domain structure of, 2050
as storage elements for digital computers, 1053, 3049
very small particles, anomalies near Curie point, 3007
Ferromagnetic materials, alloys, Al-Si-Fe, magnetoresistance of, 125
alcomax III, preferred direction in, 2342
alnico-5, magnetostriction in, 2344
Co-Ni, Hall effect in, 3625
Fe-Ni, magnetostriction in, 2345

World Radio History

Ferromagnetic materials, alloys, Fe-Ni-Mo, vibralloy, **124**
Gd-Mg, properties of, **127**
high-strength, origin of damping in, **3622**
Mn-Bi, preparation and permanent-magnet properties of, **1035**
Ni-Mn, properties of, **3025**
permalloy, noise of, space correlation of, **3029**
permanent-magnet, Co-Pt, properties of, **(D)2709**
perminvar, magnetization characteristics of wire under tension, **2703**
Si-Fe, anisotropy of coercive force in, **2704**, grain-oriented, **3030**
Si-Fe sheet, field effect on hysteresis loop of, **126**
ultrathin tapes for h.f. cores, **760**
α-Fe and Fe alloys, structure of, **3027**
armco iron, Hall effect in, **3625**
$BaFe_{12}O_{19}$, sintered, preferred crystal orientation in, **1036**
$BaFe_{18}O_{27}$, crystal structure of, **754**
with high crystal anisotropy, **752**
Co compounds with perovskite structure, **2701**
coercive force of, effect of small ellipsoidal inclosures on, **3026**
with complex conductivity, eddy-current losses in, **1400**
for cores, properties of, **3635**
of small transformers, improvements in, **761**
dilute iron-powder mixtures, approach to saturation in, **2337**
domains in, investigations of, **749**
effect of current or stress on magnetization characteristic of, **1704**
effective atomic distances in, **1393**
Fe, high-purity, effect of dissolved O on properties of, **1034**
Fe and Ni, temperature variation of Hall effect in, **1706**
Fe single crystals, temperature dependence of magnetoresistance of, **2044**
ferrites, Co, variation of magnetostriction with composition, **131**, variation of magnetostriction with temperature, **132**
Co and Ni, magnetostriction of, **1399**
coaxial-line measurement of constants of, **1742**
double refraction of microwaves by, **755**
ferroxcube, properties of, measurement of, **3060**, properties and applications of various grades of, **750**, **1395**, **(C)2042**, **(C)2702**
magnetic quality factor μQ as criterion for, **1707**
Mg, neutron diffraction study of, **3335**
Ni, Hall effect in, **1398**
Ni-Zn, magnetic viscosity of, **3621**
parameters of magnetostrictive vibrations in, **3624**
permittivity and permeability of 6·6-cm λ, **(C)1401**
possible applications of, survey of, **1396**
sintered, developments in, **3334**
specific heat discontinuity in, **3623**
spontaneous magnetization of, **1397**
structure and properties of, review of, **2043**
temperature dependence of magnetic spectrum at v.h.f., **1312**
in waveguides, properties and applications of, **931**
ferrites and iron powders, r.f. measurements on, N.B.S. methods, **2074**
ferroxdure, properties of, **751**
haematite, crystal structure and antiferromagnetism in, **1311**
thermomagnetic properties of, **2705**
influence of grain size on coercive force, **2341**
influence of magnetic field on polymorphic transformation in, **2339**
magnetic after-effects in, **2041**
magnetic viscosity under discontinuous and continuous field variations, **123**
metals, effect of spontaneous magnetization on resistance of, **1402**
thermal and thermoelectric properties of, **1394**
microwave Faraday rotation in nonsaturated condition, **1709**
Ni, and alloys, in valve manufacture, **3629**
magnetostriction and Δ-E effect in, **1038**
temperature variation of magnetization of, **1033**
Ni-Cr steels, effect of fatigue on magnetic properties of, **1037**
nonuniformly magnetized, determination of coercive force of, **3024**
particles, motion in field of electromagnet, **1663**
motion in rotating magnetic field, **1664**
powders, Fe and Cu-Ni-Fe-alloy, production and application of, **762**
iron-oxide, magnetic properties of, **2338**
permalloy and iron, gyromagnetic effect in, **757**
with rectangular hysteresis loop, performance under current-pulse conditions, **128**
relation between hysteresis coefficient and permeability of, **756**
temperature-sensitive, survey and applications of, **3338**
Ferromagnetism, collective electron theory of, **1968**
and overlapping energy bands, **1662**
Ising model of, theory of, **2964**
quantum theory of, **2340**
theory of, **3586**
and electron-spin degeneracy, **1001**
and Heisenberg's model, **1003**
Zener's, **1002**
Field strength, (See also Reception; Television; Wave propagation, e.m.)
near antipode of transmitting station, calculation of, **2779**
'fixed-level' recording method for, **2065**
v.h.f., influence of ground on measurement of, **2389**
over irregular terrain, in u.h.f. 300–900-Mc/s television band, **1786**
for long transmission paths, calculation of, **2778**
low-level, signal-generator method for measurement of, **1061**
meters, commercial, N.B.S. calibration of, **773**
500–700-Mc/s, **156**
at Riverhead, N.Y., of station KC2XAK, at 534·75 Mc/s, **1113**
sky-wave, h.f., graphical calculation of, **199**, **2777**
Field strength, of Swiss broadcasting stations, **2424**
of television transmissions, measurements by helicopter, **576**
at 93 Mc/s, for paths of 40–150 miles, analysis of, **809**
Films, (See also Sound recording; Television)
thin, CdO, sputtered, conductivity and structure of, **133**
conducting, on glass, N.P.L. method for, **3340**, PbS and Te, capacitance effects in, **2682**
dielectric, on Al, conductivity distribution within, **3528**
evaporated, Ag and Ge, contamination by heater material, **758**, Au, preparation and properties of, **430**, Cu and Ag, mean free paths of conduction electrons in, **714**
Fe, effect of magnetic field on resistance of, **1039**
Ge, production by evaporation from carbon crucible, **3032**
metal, deviations from Ohm's law in resistance of, **2685**, evaporated, electrical conductivity of, **3031**, in longitudinal magnetic field, conductivity of, **3626**, resistance variation with applied potential, **3339**
Mo, with SiO coating, time variation of resistivity of, **429**
Ni, sorption properties of, **3271**
of oxide on Al, ionic current and growth of, **2347**
Pt, covered with dielectric layer, resistance of, **134**, resistance variation with applied direct voltage, **3577**
Te, effect of electric field on conductance of, **1695**
uniform, evaporation technique for, **428**
Filters, (See also Networks)
acoustic, multilayer, **912**
a.f., using negative feedback, **3545**
resonant, high-Q, **351**
analysis and design of, graphical methods for, **(D)349**
band-pass, cm-λ, using coupled cavity resonators, bandwidth of, **1935**
multistage, with nearly rectangular response curve, **1613**
using quartz-crystal resonators, design of, **3552**
u.h.f., using waveguides and coaxial-line resonators, **1933**
wide-band, two-stage, graphical calculation of transmission range of, **57**
Zobel and Laurent, unitary design system for, **3236**
8–13-c/s, **3237**
bridge-type, symmetrical, design by use of operating-parameter theory, **3235**
coaxial-line, band-pass and high-pass, **669**
constant-k, termination variation in, **3233**
coupling-free, systematic design procedure for, **1612**
design of, Wagner's methods for, **1931**
electromechanical, i.f., **1615**
electronic, variable-bandwidth, synthesis of, **2925**
with generalized parameters, calculation of, **(C)56**
ladder, attenuation chart for various types of, **(A)961**, **3544**
design of, **1932**
effects of terminations on insertion loss of, **2596**
low-pass, formulae for, **666**
lattice, antimetrical, theory of, **2597**
low-pass, linear-phase, design of, **1614**
Tchebycheff-type, formulae for, **962**
with minimum number of inductors or capacitors, design of, **2595**
with minimum number of resonators and minimum no-load Q, **3543**
multiple-resonant-circuit, alignment of, **(C)1268**
n-mesh, RC, admittance and transfer functions of, **1934**
nonlinear, for detection of sine-wave signals in noise, **206**
optimum, **2598**
optimum, for detection of signals in noise, **205**
linear, Wiener's theory of, simplified presentation of, **2280**
new procedure for design of, **2924**
r.f. and i.f., transient response of, **(A)350**, **963**
semifinite-terminated, design of, **2923**
statistical, nonlinear, **667**
and switches, u.h.f., for London/Birmingham television relay link, **951**
Tchebycheff-type, numerical calculation of, **668**
theory and technique of, fundamentals of, **665**
transfer function of, synthesis of, **1611**
and transmission lines, transient response of, formulae for, **1248**
waveguide, direct-coupled, narrow-band, synthesis of, **58**, **(D)3234**
Fluctuations, (See also Noise)
electrical, theory of, **2288**
random, history of investigations of, **908**
Fluoroscopy, electronic intensification of images in, **1098**
Fluxmeters, rotating-coil, **1430**
Frequency, (See also Analysers; Analysis)
absolute, estimation of in 1950–1951, **(A)153**, **1058**
allocations, international, for maritime distress signals, **829**
calibrator, 0·25–250-Mc/s, **1751**
changers, magnetic-cross, for subharmonic generation, **3502**
using Type-DK92 heptode, for 3·3–30 Mc/s, **813**
control, automatic, theory of, **3214**, **(C)3524**
converter, for adapting s.w. receiver to 200-kc/s reception, **3698**
dividers, locked-oscillator, using nonlinear elements, **1281**
stable, using thyrite elements, **3560**
elimination, by transconductance bridge, **59**
instantaneous, concept of, **2908**
measurement, accurate, **1069**, a.f., **1738**
of f.m. transmission, by pulse counting, **3660**
meter, automatic, for very low frequencies, **3375**
cavity-resonator, for range 22–37 kMc/s, **3668**
direct-reading, 30 c/s–30-Mc/s, **171**
reed-type, 5–270-c/s, **1079**
rapidly varying, instantaneous measurement of, **1428**
rate indicator for mains-frequency control, **1137**

World Radio History

Frequency, stabilization. See Stabilization, frequency.
standard, (See also Standard-frequency transmissions)
N.B.S., improvements in, **1731**
1-Mc/s, derived from WWV signal, **456**
substandards, microwave, N.B.S., and calibration service, **2063**
using transistor oscillator and 100-kc/s quartz crystal, **2064, 3051**
100-c/s–100-kc/s, portable, **3070**
synthesis, for range 1 kc/s–100 Mc/s, **2376**

Galactic radiation. See Cosmic radiation.
Galvanometers, coupled, Brownian fluctuations in, **2077**
induction, as sensitive d.c./a.c. converter, **3666**
matching of thermocouples to, **2387**
moving-coil, extreme-sensitivity, **2076**
resonance, transformer-coupled, **2388**
valve, logarithmic-scale, **3363**
Generators, (See also Noise; Oscillators; Signal generators; Sound)
e.s., rotary, 100-kV, **2459**
van de Graaff, 1-MV, for ion accelerator, **184**
h.v., Cockcroft-Walton voltage-multiplying circuit for, **2151**
for c.r.o. and television equipment, **2812**
impulse, 3-MV, standard-waveform production with, **974**
surge-wave, repetitive, **1088**
Geomagnetic storms, and aurora, theory of, **1013**
35- and 74-Mc/s pulse echoes during, **2976**
characteristics of storm of 3rd Aug. 1949, **2644**
M-type, correlation with monochromatic corona, **2975**
morphology of, **2645**
new theory of, **2648**
polar, constitution of, **2977, 2978**
recurrence tendency of, **2974**
reverse pulse preceding sudden commencement of, distribution of, **2973**
and sunspots, **2641**
theory of movement of, **100**
Jan.–June 1952, **400,** March–Sept. 1952, **1339,** July–Dec. 1952, **1988,** Oct. 1952–March 1953, **3284**
Geomagnetism, correlation with solar activity, **1011**
disturbances, diurnal and storm-time variations of, and ionosphere, **3300**
international data, first quarter 1952, **401,** second quarter 1952, **1340,** third quarter 1952, **1989,** fourth quarter 1952, **3285**
variation of recurrence interval with solar cycle, **1335**
field for epoch 1942, harmonic analysis of, **3279**
field variations, during bay disturbances, **2972**
diurnal, and electrical conductivity of upper atmosphere, **2647**
eleven-year, analysis of, **1337**
mean, and secular, in Adélie Land, May 1951–Jan. 1952, **2305**
and rate of earth's rotation, **1338, 3281**
secular, at Colaba and Alibag, India, **399,** in New Zealand, **3282**
solar-flare type, and integrated conductivity of ionosphere, **2663, 2664, 2665, 2666**
two-dipole model for, **1012**
K-indices, at Abinger, Eskdalemuir and Lerwick, July–Aug. 1952, **398**
at Cheltenham, April–June 1952, **397,** July–Sept. 1952, **1336,** Oct.–Dec. 1952, **1987,** Jan.–March 1953, **3280**
micropulsations, statistical treatment of, **2643**
and sunspots, **2642**
Geophysical prospecting, equipment for, **2749**
Graphite, artificial, resistivity of, influence of coke-calcining temperature on, **1041**
crystal structure and physical properties of, **1411**
electrical properties of, **2051**
Ground, conductivity of, determination from wave attenuation and range data, **3687**
Gyrators, (See also Faraday effect)
acoustic, **1874, 2532**
using Faraday effect in plasma, **1265, 3232**
using Hall effect in Ge, **1930**
microwave, using ferrite-cored waveguide, reduction of loss in, **1610**
three-terminal, **3228**

Hall effect, a.c., in semiconductors, recording apparatus for, **1057**
in BaO single crystals, **129**
in Fe and Ni, temperature variation of, **1706**
measurement of, geometrical arrangement in, **3054**
and related thermomagnetic and galvanomagnetic effects, **713, (C)1975**
and resistivity, connection between, **1319**
in Ti, **2049**
Hearing aids, using transistors, commercially available models, **1903**
audibility of frequency vibrato, influence of nonlinear distortion on, **2870**
masking of tones by noise as function of interaural phase, **9**
and memory for acoustic effects, **306**
perception of a.m. and f.m. of pure tones, **303**
perception of a.m. tones, **1883**
perception of nonlinear distortion in transmission of musical intervals, **304**
process of speech perception, **920**
stereophonic, theory of, **2546**
threshold of, for loudness and pitch variations, **1892**
Heating, h.f., dielectric, **1453,** correlation of temperature and field strength during, **500**
Heating, h.f., induction, bibliography on, **3676,** for hardening band-saw teeth, **179,** of metals, **1452**

Image converters, as high-speed shutters in photography, **2751**
for observation of very-high-speed phenomena, **1763**
Impedance, (See also Acoustics; Aerials; Networks; Transmission lines)
acoustic, absolute measurement of, **917**
measurement of, by resonance method, **2545** by transmission-characteristic method, **2868,** using water-filled tubes for, **2866**
characteristic, of coaxial cable, frequency-sweep measurement of, **(D)3058**
electrical and acoustical, incomplete analogy between, **4**
complex, meter for, 30-c/s–15-kc/s, **2741**
diagrams, geometrical transformation of, **2576, 2907, (C)3494**
matching, frequency-independent transition between coaxial cable and balanced line, **3478**
with $\lambda/4$ sections, charts for bandwidth in, **30**
and measurement at v.h.f., **1747**
with modified exponential transmission lines, **3533**
with transmission-line transformer sections, **2249**
u.h.f., termination for waveguides or coaxial lines, **1073**
wide-band, of coaxial cable to waveguide, optimum piston position for, **1260,** with directional coupler, **29**
measurement, a.f. to v.h.f., shunted-T circuit for, **1062**
equipment for range 50–500 Mc/s, **478**
on helix of travelling-wave valve, **3753**
microwave, using double-slug transformer, **774,** 3-probe method of, **462**
u.h.f., equipment for coaxial cables, **2393**
meters, for crystal units, **2390**
of parallel conductors, proximity-effect formula for, **2918**
Smith-chart plotter, automatic, **3065**
Impedors, termination, maximum power in, **1258**
Induction, of current in wide conductor by narrow conductor carrying h.f., **81**
of currents in disk by creation of magnetic poles, **708**
magnetic, null method for measuring, **1744**
Inductors. See Coils.
Instruments, measurement, error of, **1074**
for microwave measurements, **(D)3362**
Insulating materials, (See also Ferroelectric materials)
araldite, properties of, **138**
$BaTiO_3$, transition energy and volume change in, **2053**
brush-discharge ionization in, **136**
ceramics, $BaTiO_3$-$BaSnO_3$-$SrTiO_3$, properties of, **1718**
niobates and tantalates, **137**
titanate, potential distribution in, **439**
glass, tellurite, **143**
glass-fibre paper, properties of, **1719**
glasses, borosilicate, power factor as function of composition of, **443**
IN-420 chlorinated impregnant, properties of, **3633**
laminated plastics, properties of, **2353**
liquid, fluorinated, properties of, **(A)3037**
modern, r.f. properties of, **1716**
organic, new polymers and synthetic resins, **3634**
polyvinyl chloride, properties and application of, **1720**
rare-earth titanates with perovskite structure, **1717**
relation between breakdown strength and mobility of charges in, **1375**
relation between high-voltage polarization and intensity of electric field, **2681**
rubber, electrical properties of, **2055**
semiconducting ceramic glazes, properties of, **438**
SF_6, r.f. electric strength of, **3627**
silicone resins, for use at power frequencies, **2352**
silicone rubber, properties and applications of, **2054**
theory of, **1372**
TiO_2, properties of, **1048**
TiO_2 (rutile), effect of impurities on conductivity of, **2883**
physical properties of single crystals, **434**
Intercommunication systems, noise reduction in, **2787**
Interference, from automatic telephone apparatus, suppression of, **1476**
in broadcasting and television reception, problems of, **1179**
from carrier-current circuits on overhead power lines, reduction of, **1794**
co-channel, ground/air, at 2·9 kMc/s, **1798**
from electric railways, Swiss investigation of, **2131**
evaluation by means of noise filters, **2430**
from fluorescent lamps, suppression of, **2133**
in f.m. and a.m. reception, from unwanted transmitters, **531**
from h.v. lines, investigation of, **2431**
from ignition systems, in television, relative sensitivity of vertical and horizontal dipoles to, **1180**
impulse, in television receivers, reduction of, **1843**
in long-wave reception, loop aerial for elimination of, **35**
measurements in aircraft, double-beam c.r.o. for, **2075**
in radiotelegraphy, due to adjacent-channel transmissions, **540**
from television receivers, reduction of, **2476**
in television reception, apparatus for demonstrating various types of, **2174**
from aurora, **1173**
from bus bells, **577**
from f.m. u.s.w. receivers, maximum value of, **867**
and its suppression, **2173**
Interferometers, electron-beam, using 3-crystal beam splitter, **3074**
ultrasonic, **1223**

World Radio History

Interferometers, ultrasonic, for high fluid pressure, 2542
Ionization, thermal, use of cm waves in study of, 3268
Ionosphere, (See also Absorption; Atmosphere; Recorders; Wave propagation, e.m.)
abnormalities at high latitudes, 1672
conditions in, and radio 'weather', 2417
conductivity of, and 'dynamo' currents in, 1352, 1353
integrated, and solar-flare type of variation of geomagnetic field, 2663, 2664, 2665, 2666
currents, in auroral zone, 2648
and geomagnetic tides, 2312
D layer, formation of, 2652
r.f. absorption over Singapore and Slough, 2660
D and lower-E layers, model deduced from long-wave measurements 2306
disturbances, forecasting of, 3288
index for, 3302
in N. America, maps of, 3296
during severe geomagnetic storms, characteristics of, 2987
of 23rd–28th Feb. 1952, 101
effects of crossed magnetic and alternating electric fields in, 1995
E layer, definition of critical frequency and measurement of ionization of, 721
effect of solar eclipse 25th Feb. 1952, 1675, 1994
h'f curve for, statistical study of minimum frequency in, 2654
ionization in, determination by V-2 rocket method, 3291
ionizing effect near sunrise, 1346
lunar effects on, theory of, 385
moving clouds of ionization in, 2310
production in O_2-dissociation region, 723
winds and turbulence in, investigation of, 1676
E and F_1 layers, at high latitudes, solar effect on, 406
E_s layer, over Calcutta, nature and origin of, 3292
electron collision frequency in, 3299
electron density in, and layer heights of, 3598
vertical distribution of, 409, (D) 1997
F layer, effect of solar eclipse of 9th May 1948 on, 2658
transient disturbances in, 404
triple splitting in, 3295
$F_{1\cdot5}$ layer at Dakar, and motion of sun, 1347
F_1 and F_2 layers, comparative increases of ionization from sunspot minimum to maximum, 1993
F_2 layer, critical frequency, variation with sunspot number, 2657, world distributions of, 2984
disturbance in, relation to geomagnetic storminess, 2986
electron density, below maximum-ionization level of, 1349, night variations of, 2656
over equatorial Africa, effect of solar eclipse 25th Feb. 1952 on, 1327
frequency-sweep measurements of height of, 3297
longitude effect in, (D) 2307
lunar effect on median height of, 405
mechanism of electron removal from, 3298
night-time recombination-coefficient and temperature variations of, 2662
solar tides in, 1348
storm phenomena in, 2982, 3304, classification according to characteristics and world distribution, 2983, geomorphology of, 1673
variations accompanying geomagnetic storms, 3303
frequency of occurrence of fE_s and $fmin$F, 2985
and geomagnetism, diurnal and storm-time variations of, 3300
variations associated with, morphology of, 3301
h't measurements at Wakkanai, Japan, during eclipse of 9th May 1948, 2659
ionization over auroral zone during geomagnetic storms, 2991
irregularities in, investigation by means of galactic r.f. waves, 722, 1674
motion of, wave hypothesis of, 2655
layer heights, calculation of, taking account of geomagnetic field, 3290
measurements at oblique incidence over Eastern Australia, 807
long-delay echoes at 150 kc/s, 1992
low-level echoes, correlation with abnormally high absorption in, 519
lower, long-duration back scatter of 33-Mc/s pulse signals from, 2000
phase change of pulse echoes, measurement of, 3599
properties of, rocket investigations of, 726
recombination coefficient for, determination of, 2653
recording stations, world list of, 2668
research at Kodaikanal observatory, 392
review for 1952, 1016
shielding effect of, 2667
'sluggishness' of, 3289
sounder, automatic, 3356
Berkner-Wells-Seaton type, improvements to, 725
frequency-sweep, 724
high-precision, 1677
oblique-incidence, COZI communication-zone indicator, 3600
storms, in auroral zone, 3293
and F_2-layer geomagnetic anomaly, 2308
Japanese investigations of, 2988
warning system, B.B.C., 103, value of, 2110, (D) 2767
sunrise effect at Kodaikanal, 1345
travelling disturbances in, 3294
diurnal variation of direction of, 2309
winds in, heights of, long-wave measurements of, 2311
measurements of, 1996, using 3-receiver technique, 720
Ions, gaseous, recombination of, review of, 999
motion of, in strong electric field, 376, 1649

Laboratories, acoustics, at Physikalisch-Technische Bundesanstalt, Brunswick, 2
electroacoustics, at School for the Deaf, Worcester, C.P., 3
Lenses, (See also Aerials; Electron lenses)
ion, grid-type, focusing properties of, 3387
microwave, delay, metal strip, experimental verification of theory of, 3485
effects of astigmatism on diffraction pattern and gain of, 1597
excitation and radiation of, 3486
lattice, for cm waves, 1595
new type of, 937, 3483
for phase correction with horn aerials, 1242
refractive index of delay media for, 3652
scanning aberrations of, 731
spherically symmetrical, 1596
for wide-angle scanning, 3484
optical and electron, representation of by resistive quadripoles, 3084
plastic, for high-intensity ultrasonic radiation, 915
Light, nature of, experimental investigations on, 1292
velocity of, determination by band-spectrum method, 987
Lightning, air discharge, and flash to ground, Boys-camera study, 1682
and positive charge at bottom of thundercloud, 1683
radar observations of, 2003, 3306
wave spectrum of, and propagation of very long e.m. waves, 802, 1772
Limiters, band-pass, signal/noise ratios in, 3401
impulse-noise, diode, for mobile v.h.f. receivers, 2780
Loudspeakers, (See also Public-address systems; Sound)
acoustic damping for, 3179
baffles and cabinets for, 2201
characteristics in relation to room acoustics, 3469
corner-type, historical development of, 3178
friction-driven, using electromechanical amplification, 614
horn-loaded, 314
Ionophone, as ultrasonic generators, 2539
metal-cone, development of, 18, 313
and pickups, objective testing of, 19
reverberation-room measurements of efficiency of, 2873
subjective and objective tests on, relations between, 2202
transient distortion in, assessment of, 17
Luminescence, (See also Electroluminescence; Phosphors)
of alkali halides after c.r. excitation, decay of, 2680
of layers and films with polyvinyl alcohol as binder, 2955
quenching action of r.f. field on, 1370

Magnetic field, of current element near edge of conducting half-plane, 2967
above and below infinite corrugated sheet, 2965
measurement with iron-cored magnetometer, 165
due to permeable conducting sphere near coil carrying a.c., 2966
and rotation of massive bodies, negative experiment on, 1333
of thick plate with semicylindrical edge, 2293
——**force,** practical calculation of, 3587
——**materials,** measurements of moment, susceptibility and permeability, 472
——**properties,** of metals, theory of, 1004, 1005, 1967
of stainless steel wire, 1708
Magnetism, antiferromagnetism and ferrimagnetism, review of, 1000
definition of quantities in, 1966
leakage flux of relays; calculation of, 387
post-war developments in, 87
relation between coercive force and crystal energy, 753
Magnetization, spontaneous, of antiferromagnetic single crystal, temperature dependence of, 3336
condition for vanishing below Curie temperature, 3337
Magnetometers, microwave, based on Faraday rotation in ferrites, 1072
rotating-iron, 1730
Magnetostriction, of Co and Ni ferrites, 1399
constants of single crystals, 2045
factors contributing to overall effect in, 130
reversal of sign of by expansion, 1711
in single crystals and multicrystal materials, 1976
in strong fields, theory of, 3028
Magnets, permanent, iron-powder, 3038
optimum design of, (A)3039
Mathematics, algebra for networks containing switches, 2913
boundary-value problems, use of Tchebycheff-polynomial operators in numerical solution of, 2713
differential equations, of oscillations, numerical and graphical integration of, 1413
theorem in theory of, and application to analogue computers, 2721
in theory of forced oscillations in triode circuit, 971
Dirac's function, application in mathematical physics, 2821
elliptic functions, coordinate systems associated with, 3347
Fourier series, tables of, 2360
Green's functions and impulse functions, tables of, 2360
integral variant associated with wave equation, 144
interpolation in series of correlated observations, 2362
Laplace transformation, general rules for, 764
interpretation of, 3041
linear equations, systems of, solution by minimized iterations, 145
linear stochastic operators, autocorrelation functions of, 3348
Mathieu-Hill type equations, matrix solution of, 3640
matrix, formula for power of, proof of, 2253

World Radio History

Mathematics, matrix calculus and use of 'normalized magnitudes' in electrical engineering, **3639**
Maxwell's equations, first boundary-value problem of, **1641**
prediction of nonstationary stochastic processes, theory of, **445**
probability theory, and application to e.m. propagation, **197**
step functions, resolution of, **763**
tabulated values of wave-theory function for complex arguments, **444**
Measurement, (See also individual subjects)
h.f., use of frequency converters in, **155**
techniques, for various components, **457**
Metallization, of insulator surfaces, techniques for, **2346**
precious-metal, of insulating materials, and coating test methods, **2052**
Metals, band structure of, review of, **2046**
Meteors, night-time streams, 1946–1951, radar observations of, **108**
sporadic, velocity distribution of, **1009, 1010**
trail echoes, decay of, **1977, 1978**
double-Doppler investigation of, **393**
experimental study of, **1979**
long-duration, at 33 Mc/s, **2000**
1950 δ-Aquarid shower, radar investigation of, **1320**
Meters, grid-dip, u.h.f., using series-capacitance-tuned oscillator, **2080**
ratio, for determination of reflection coefficient of transmission system, **466**
resistance and conductance, electronic, **(A)170**
s.w.r., slotted-waveguide, for 9·5-kMc/s band, **3368**
using waveguide squeeze-section and c.r.o., **3066**
Microammeters, integrating, for currents $> 10^{-8}$A, **1431**
d.c., with full-scale ranges from 10μA to 1 mA, **1745**
Microphones, absolute calibration methods for, **3173**
capacitor, free-field reciprocity calibration of, **2544**
input resistance of, **(D)16**
tension of diaphragms, measurement of, **2200**
Types M49, M50 and U47, **1230**
probe-type, for measurement of sound pressure, **1898**
ribbon-type, directional, **2199**
sensitivity to stray magnetic fields, **1897**
on surface of sphere, directivity of, **613**
Microphony, in superheterodyne-receiver oscillators, **814**
Microscopes, (See also Electron microscope)
flying-spot, **1759, 3073**
Microwaves, (See also Instruments; Measurement; Wave propagation, e.m.)
industrial use of, possible dangers in, **1093**
physiological effects of, **2748**
Mixers, crystal, microwave, calculations of characteristics of, **2941**
Ge-crystal, for u.h.f. receivers, testing of, **2083**
harmonic, using crystal diodes, **1791**
Modulation, a.m., Rothman system of, **1181**
a.m. and f.m., spectra of, analysis of, **2790**
a.m., f.m., and ph.m., theory of, **2439**
comparison of different methods for directional radio links, **2791**
comparison of signal/noise ratios for different methods, **828**
definitions of terms for, 53 IRE 11S1 standard on, **2438**
frequency, by means of reactance units, fundamentals of, **2820**
index, of f.m. signals, oscilloscope determination from stationary phase points, **3071**
low- and high-level, for television transmitters, comparison of, **567, 568**
pulse, multiplex, pulse distributors for, **2142**
new method with reduced bandwidth, **3415**
pulse-code, delta, **3712,** principles of, **543,** simple method of producing, **2440**
systems of, **3106**
Modulators, amplitude, using carrier-frequency switching pulses, **2177**
clamp-valve, carrier control with, **1182**
using class-B amplifiers without grid current, **3249**
frequency, using diode, **2485**
serrasoid, **1846**
using Hall effect in Ge, **1930**
magnetic, for pulsed radar, **2992**
phase, susceptance valves and reactance valves as, **3442**
rectifier, carrier-leak control by use of d.c. meter in, **580**
with frequency-selective terminations, input impedance of, **579**
using transistors, **1514**
for u.h.f. television, using spiral-beam valve, **2188, 2500**
Monitoring, of B.B.C. unattended transmitters, **548**
international, E.B.U. station at Jurbise-Masnuy, **3416**
of radio-communication channels, automatic-scanning receiver for, **2122**
stations, N.W.D.R., **2148**
Monitors, frequency-shift, c.r., B.T.R., **1436**
panoramic, multiband, v.h.f., for county police and fire-services' transmitters, **544**
for s.s.b. s.w. transmitter, **2175**
for television waveforms, **1736**
for u.h.f. television transmitter, **247**
waveform, Type-500, for recurrent waveforms, **482**
Multivibrators. See Oscillators.
Music, aesthetics of, conditions relating to, **1882**
Musical instruments, electronic, **317**
'chord' organ, **616**
clavioline, **318**

Navigation aids, (See also Radar)
aerial, for civil aircraft, review of, **1024**
distance-measuring equipment, **3315**
errors in, dynamic aspects of, **412**
Navigation aids, aerial glide-slope receiver Type 154A, **413**
instrument-landing approach-system steering computer, **1369**
loran, continuous-indicating equipment for, **2319, 2998**
punched-card-controlled course-line computer for, **2674**
survey of, **2996, 3419,** with special reference to Holland, **2010**
beacon, small, SARAH, for location of lost airmen, **2995**
Decca, chart calculations for, **2009**
French service area and error curves, **3313**
site and path errors over land, **1025**
marine, aboard merchant ships and fishing vessels, **3418**
and radar, in ocean weather ships, **1023**
radar chart-matching devices, **1022**
Rana, **3314**
Networks, (See also Circuit theory; Filters)
analysis by repeated voltage superposition, **655**
bridged-T, equalizing action of, **2254**
delay, with maximally-flat characteristics, applications of, **(C)54, (D)2259**
group-delay time in, measurement of, **3659**
gyrator. See Gyrators.
hybrid-ring, wide-band, for u.h.f., **960**
with input impedance or transfer admittance of constant magnitude or phase for varying load, **2251**
iterated, and application to differentiators, **2253**
ladder, exact amplitude/frequency characteristics of, **1267**
'reciprocal', properties of, **2589**
RX, response characteristics of, **(D)3222**
lattice, *RLC*, synthesis of, **3535**
linear, active, transformations of, **956**
algebraic theory of, **3229**
with optimum signal/noise ratios, design of, **1927**
response to input with linearly varying frequency, **664**
theory of, **2245**
nonlinear, multipole, theory of, **3546**
steady-state response of, graphical analysis of, **3540**
notch, design curves for, **2255**
n-terminal-pair, synthesis of, **1617**
parallel-T, dual-input, **3537**
RC, analysis of, **661**
parameters of, determination of at v.h.f., **1435**
passive, mathematical 'trees' for solution of, **2587**
measurement of 'A'-matrix elements of, **1605, (D)3227**
2-*n*-terminal, synthesis of, **1616**
phase-shift, simplified treatment of, **3230**
quadripole, analysis by method of general circuit constants, **2252**
cm-λ, experimental determination of characteristics of, **1733**
cm-wave attenuation factor of, measurement of, **2071**
with f.m. or ph.m., harmonic distortion in, **1282**
linear, equalization of transfer characteristics, **1936**
passive, rigorous theory of, **1264,** transfer matrix in terms of image parameters of, **1604**
phase and group delay of, **2258**
reactive, impedance-transforming properties of, theorem on, **3541**
with reactive elements, synthesis of, **1263, 3538**
response to discontinuous signals, mathematical theory of, **957**
series-parallel, realizability conditions for, **3225**
spinor theory for, **3226**
transient response of, calculation of from frequency response, **3542**
including transistors, terminology and formulae for, **2238**
waveform computations by time-series method, **55, 959, (D)1608**
RC, analysis of, **2593**
equivalent *Q* of, **2919, (D)3221**
maximum gain of, **1606**
multimesh, for phase-shift oscillators, **1627**
synthesis of transfer functions for, **1929**
tolerance coefficients for, **3224**
variable-frequency, with single variable element, **958**
3-terminal, cascaded, synthesis of, **656,** paralleled, synthesis of, **3536**
reactive T or Π sections, conditions for resolution into matched half-sections, **2590**
RLC, unbalanced, synthesis of, **2256**
second fundamental theorem of, **2585**
with sine-squared impulse response, synthesis of, **348, (D)1609**
stability criterion for, **2231**
containing switches, algebra for, **2913**
synthesis of, approximation method for, **660, (C)2250**
potential-analogue method, **3530**
T, applications of, **1928**
resistive, as bidirectional couplers, **2592**
theorem for, and applications of, **62**
critical discussion of, **1607**
theory of, practical significance of complex frequencies in, **657**
Wiener's theory of stationary time series, **328**
time-equalizer, variable, for video-frequency waveform correction, **1178**
transformations to equivalent forms, **2586**
transformer, ideal, theorem on, **1266**
transient phenomena in, calculation by means of Fourier integrals, **1926**
varying-parameter, *n*-mesh, stability of oscillations in, **1271**
2-terminal, impedance functions of, **2248**
nonlinear, theory of, **3220**
theorems on, **3532**
2*n*-terminal, with minimum number of elements, synthesis of, **3238**
3-pole and multipole, equivalent circuits using negative 2-pole elements, **2247**

World Radio History

Noise, (See also Atmospherics; Cosmic radiation; Solar radiation; Sound)
acoustic, in sea, and sound-signal reception, **106**
in a.m. amplifiers, **368**
background, effect on frequency of valve oscillators, **1945**
carrier-frequency, on power lines, **3705**
comparator, microwave, N.B.S., **2081**
in conductors, differential law of thermal electrical fluctuations and influence of skin effect, **2951**
contact, in CdS single crystals, **3023**
in semiconductors, **2334, 3022**
temperature dependence of, **2952**
theory of, **79**
current, in Ba-Sr-oxide coating, **1532**
in metal contacts, **3498**
in semiconductors, **748**, re-examination of Bernamont's data on, **747**
in damped oscillatory circuits, quantum effects in, **3243**
in diodes, power spectrum of, and valve conductance, **1198**
in electron streams, calculation of, **891**
eliminator, 'codan', for a.m. receivers, **2132**
flicker, due to interface layer in oxide cathodes, **1531**
flicker-effect constants, measurement of, **2725**
flicker and shot, space-charge reduction of, **281**
in Ge filament, **122**
effect of magnetic field on, **2695**
generator, for S and X bands, **788**
intermodulation, in multichannel telephony systems, **827**
low-frequency, in electrometer valves, measurements of, **1185**
in valves, **1192**
mathematical representation of, **693**
measurement, accuracy of, with square-law detector, **2724**
and assessment, **3406**
53 IRE 7S1 standard on, **3055**
in microwave superregenerative amplifier, **1948**
narrow-band, probability density of, **816**
in receivers and amplifiers, survey of, **815**
reduction, in intercommunication systems, **2787**
r.f., from h.v. power lines, and power-line design, **927**
in screen-grid valves, **1538**
shot, in gas discharges, **2185**
in Ge filaments, **2035**
in semiconductors, calculation of, **2040**
in sound recording and reproduction, 53 IRE 19 S1 standard on methods of measurement of, **1900**
in telecommunication cables, measurements of, **3182**
thermal, clipped, autocorrelation function and power-density spectrum of, **532**
transistor, circuit problems of, **643**
meter for, **2385**
in transistor amplifiers, **1288, 2279**
valve, **1864**
at frequencies $> 10^8$c/s, **907, 3758**
low-frequency, measurements of, **1202**
due to oxide-cathode interface resistance, **1530**
at very low frequencies, in semiconductors, **2039**
v.h.f., total, measurements of at typical sites, **817**
v.h.f. receiver design in relation to, **1789**
Nucleonics, industrial applications of, **495**
β-particle and γ-ray thickness gauges, **496**

Optics, brightness flicker, investigation of, **1841**
direct-vision stereo-projection screen, **375**
wave and ray, in inhomogeneous absorbing media, **2954**
Oscillations, a.m. and f.m., interfering, effective value of, **1475**
spectral differences between, **2484**
of biaxial anisotropic parallelepiped, **1315**
of conducting sphere surrounded by air and ionosphere layers, **3596, 3597**
electrical and acoustic, build-up phenomena of, **1626**
in electrical circuits, analysis in terms of modulation products, **2264**
forced, in cavity resonator and coaxial-line system, theory of, **1622**
with nonlinear restoring force, **1940**
in triode circuit, theory of, **971**
in n-mesh varying-parameter networks, stability of, **1271**
nonlinear, forced, exact solutions for special cases, **2622**
periodic, stability of, **2361**
in nonlinear electromechanical systems, theory of, **3556**
relaxation, coherent theory of, **694**
subharmonic, in nonlinear systems, **2953**
in whole-anode magnetron, **904**
Oscillators, (See also Circuits; Signal generators)
a.f., transistor, low-drain, **679,** for 20, 200, 2000 and 20000 c/s **3517**
amplitude-limited, synchronization-range determination of, **1943**
amplitude-stabilized, use of servo techniques in design of, **2937**
analysis of, admittance diagrams in, **1944**
arc and dynatron, solution of 'Rukop problem' for, **2602**
beat-frequency, high-stability, 0·25–10 Mc/s, **1628**
blocking, low-power, **2936**
operation and applications of, **2606**
constant-amplitude, using clamp valve, **970**
with constant output voltage, **2939**
crystal, fundamental-frequency and harmonic, analysis of, **358**
decade, precision, 1-c/s–100-kc/s, (D)**2604**
feedback, travelling-wave-valve, **276**
filtered, calculation of attenuation in, **2449**
Oscillators, filtered, nonlinear, pull-in of, **972**
perturbations of, **1279, 1624**
f.m., quartz-crystal stabilized, **1277**
using transistor and titanate capacitor, **2938**
wide-band, with double-phantastron circuit, for data transmission, **3559**
frequency stability of, methods of improvement of, **1513**
frequency-sweep, S-band, and test set, **3671**
use of variable inductance in, **883**
wide-band, 35–900-Mc/s, for testing television equipment, **486**
X-band, **973**
470–890-Mc/s, with crystal calibrator, **487**
grounded-grid, with disk-seal valves, self-excitation of, **3245**
harmonic, using iron-cored reactor, **2455**
h.f., quenched-spark, mains-loading calculation for, **361**
for regulation and control of aircraft v.h.f. equipment, **3240**
impulse-governed, high-stability, **2607**
klystron, coherence of microwaves generated by, **2943**
long-line effects on, **363**
LC, synchronization of, mechanism of, **2940**
linear, frequency stability of, effect of noise on, **362**
locked, frequency spectrum of, **2605**
low-frequency, 0·01-c/s–1-kc/s, with output of sinusoidal, square or triangular waveform, **680**
microwave, stable, for measurement of atmospheric refractive index, **1085**
multiple-feedback, wide-range, **969**
multivibrator, anode-coupled, triggering of by negative pulses, **3557**
transistor, pulse duration and repetition rate of, formulae for, **682**
nonlinear, with noise perturbation, power spectrum of, **968, 2934**
and Nyquist diagram, **1625**, generalization of, **2232**
second-order, analysis using concept of moving poles, **2601**
pulse, hard-valve, **364**
locked oscillator, **2945**
mains-frequency, simple type of, **488**
phase-shifting, for thyratron control, **1629**
reciprocal-function, **2946**
'sine-squared', for testing television links, **1089**
for testing digital computers, **489**
wide-range, **3672**
quartz-controlled, stability of, **1274**
RC, cathode-coupled and transitron, **2935**
with electronic tuning, **1638**
sawtooth-waveform, for recording time intervals, **152**
square-pulse, high-power, **1086**
square-wave, **2944**
test-pattern, for production testing of television receivers, **2716**
transistor, **45**
analysis of, **678**
frequency-substandard, **2064, 3051**
travelling-wave-valve, **1872, 3750**
ultrasonic, ionophone, **2539**
magnetostrictive, **1556**
whistle-type, using gas and liquid jets, **1879**
valve, effect of background noise on frequency, **1945**
variable-frequency, synchronization by use of E80T valve, **2816**
v.h.f. and u.h.f., with single-crystal control, **975**
Wien-bridge, design curves for, **1278**
220-Mc/s, with TBW-6/6000 or TBL-6/6000 transmitting valve, **2270**
6-waveform, with display unit, for testing television channel, **1087**

Particle accelerators, betatron, monitor and integrator for, **2754**
theory, development and applications of, **3381**
betatron and synchrotron, automatic ejection from, **3677**
cyclotron, electric fields in dees of, **1765**
at Stockholm, initial performance of, **506**
86-in., Oak Ridge, **181**
direct-voltage generators, focusing system for, **1099**
linear, ion optics of, **2089**
portable, 250-kV, **3679**
telemetry system for, **794**
1·5-MV, for heavy particles, at Stockholm, **508**
electron cyclotron (microtron), phase stability of, **2090**
linear, for electrons, with constant wave speed, axial motion of electrons in, **3077**, using corrugated waveguide, **507**, multicavity, **509**, standing-wave, for 1·2 MeV, **3078**, waveguide-type, **2407**
for ions, motion of ions in, **2755**, effect of accelerating-field variation on, **3079**
for protons, new focusing principle for, **1766**
radial focusing in, **1455**
waveguide, dielectric loading for, **2408**
synchrocyclotron, at Amsterdam, **3076**
perturbations in magnetic deflector for, **2091**
for 450-MeV protons, **1764**
synchrotron, electron, characteristics of beam in, **2752**, energy loss in, **3380**, theory of, **182**, 35-MeV, **2093**
proton, at Birmingham, **2092**, cosmotron, effect of magnetic defects in, **2753**, focusing method for, **2406**, strong-focusing, **1454, 3678**, strong-focusing, elimination of effects of faulty alignment in, **2405**
Particles, charged, motion in e.m. field of linear current and e.s. field of cylindrical capacitor, **75**
Permeability, complex, and dielectric constant, measurement of at u.h.f., **2381**

World Radio History

Permeability, determination of, optical method for, 995
measurement, for large iron sheets, 3061
for rod specimens, 1429
Perturbation theory, accuracy of calculations from inaccurate unperturbed wave function, 3254
Phase angle, and gain, measurement set for, (A)2738
changing, for sinusoidal l.f. voltage, 330
comparator, precision, for low radio frequencies, (A)483, 1080
delay, in television transmission circuits, measurement of, 1750
measurement, with c.r.o., 1739, accuracy of, 1740
use of microwave homodyne in, 1741
meter, 2741
shifter, for range 10–100 Mc/s, 3357
variable, potentiometer-type, low-cost, 640
waveguide, for microwave measurements, 1440, modified magic-T, for microwaves, 331, wide-band, 2567
Phosphors, alkaline-earth orthophosphate, 3610
CdS crystals, electrical conductivity of, 1026
luminescence and conductivity on irradiation with α particles, 1371
crystal, mechanism of phosphorescence in, 1643, 2624
for flying-spot c.r. tubes, 3608
intrinsic efficiencies under c.r. excitation, 3607
light emission and light quenching under electron and ion impact, 734
sulphate-base, thermoluminescence of, 3006
for television c.r. tube screens, 1869
transfer and transport of energy by resonance processes in, 372
ZnF_2, luminescence decrease due to electron irradiation of, 3322
ZnS, absorption and emission spectra of, 2023
electronic transitions in luminescence of, 2679
fluorescence centres and traps in, 2024
ZnS-Cu, continuously excited, effect of electric field on, 2284
influence of fineness of material on luminescence of, 2022
with yellow and red emission, 3609
Zn_2SiO_4-Mn and ZnS-Cu, field emission of, 3321
Zn_2SiO_4, field-dependent luminescence of, 418
Zn_2SiO_4-Mn, interaction of Mn ions in, 2323
(Zn, Cd)S, induced conductivity of, 2021
(Zn, Cd)S-Ag-Au-Al, with white fluorescence, for television tubes, 111
Photocells, Ag-Cs, fatigue effects in, 3137
Ag-Cs_2O-Cs, pulse irradiation of, 3448
application of, control of tracing head of oxy-acetylene cutter, 180
register control, 1096
barrier-layer, laws governing characteristics of, explanation of, 3141
utilizing carrier injection in semiconductors, 888
electron-multiplier, 1853
cascade-type, remodulation in, 1519
dark current of, 1518, 2492
infrared-sensitive, 1520
for scintillation counting, 266, 2181, 3748
flying-spot scanner for study of surfaces of, 890
Ge, comparison of three types of phototransistor, 2825
p-n-junction, Type M-1740, properties of, 889
PbS, properties of, 2677
PbSe, in infrared spectroscopy, 3142
Sb-Cs, alternating component of photocurrent under strong illumination, 3138
Se, barrier-layer, barrier height in, 1852
Se and Ag_2S, current sensitivity of, effect of electron stream on, 3140
Se-CdO, mechanism and applications of, 3449
Photoconductivity, of anodic Ta_2O_5, 733
'barrier layer' and 'concentration' theories for, choice between, 3605
of CdS crystals at relatively high temperatures, 1687
of CdS single crystals at edge of absorption band, 1691
growth and decay of, 1688
of Cs_3Sb, and thermo e.m.f., 3002
infrared, of Si at low temperatures, 2014
of orpiment, 415
of PbS, absorption spectra of at various temperatures, 2020
and conductivity of, effect of oxygen on, 3040
of PbS layers, properties of, 2706
of ZnS, measurements on single crystals, 732
Photoelectric effect, internal, electron-optical investigation of, 3606
in natural PbS, (C)2013
——**emission**, (See also Cathodes)
of BaO, 2322
of CdS and CdSe, field-type, 1391
of CdS-Cu, at infrared λ, 2012
of Cs_3Sb, and energy structure of, 3004
measurements of energy distribution of, 1690
of Cs_2Te and Rb_2Te, 1689
——**materials**, Cs_3Sb, electrolytic conduction in, 2676
PbS, noise measurements on thin layers, 3003
PbS, PbSe and PbTe, optical constants of in 0·5–3-μ wavelength range, 2018
PbTe and Si, optical constants of, interrelation between, 2017
Photography, image converters as high-speed shutters in, 2751
Photomagnetoelectric effect, in semiconductors, measurements on Ge, 2016
theory of, 2015
Pickups, and loudspeakers, objective testing of, 19
piezoelectric, crystal, 1904
Piezoelectric crystals, (See also Quartz).
ADP, deuterated, properties of, 1044, theoretical interpretation of properties of, 1045
$BaTiO_3$ ceramics, properties of, 1042
for pressure, temperature and humidity measurements, 2403
quartz and synthetic-crystal resonators, 1376
Piezoelectric crystals, for radio applications, properties of, 3635
Rochelle salt, under compressive stress, voltage measurements on, 735
measurement of dielectric constant at 3 kMc/s, 2729
sound-wave propagation in, theory of, 3014
thickness vibrations of, 357, 3553
Piezoelectricity, ferroelectricity, and crystal structure, 699
Plasma, in crossed electric and magnetic fields, 3591
electron, longitudinal waves in, 1310
gas-discharge, absorption of microwaves by, 2970
in magnetic field, theory of, 1964
moving, origin of magnetic fields in, 1985
with neutral gas, dynamics of, 1309
oscillation, relation between various types of, 1965
and solar 'enhanced radiation', 1322
propagation of e.m. waves in, 1659
with variable current, theory of, 386
Potential, barrier, between electrodes with different applied potentials, 2628
theory of, 2629
contact. See Contact potential.
in electrically shielded space, variations of, 1646
isolating comparator for, 3064
due to uniformly charged disk, calculation of, 1651
vector, derivation from scalar potential, (A)2285, 3574
Power measurement, at h.f., using thermistors, 1441
microwave, absolute, radiation-pressure method for, (D)1071
at u.h.f., mismatch errors in, 3661
meter, for microwaves, 786
supplies, a.c., constant-voltage, (D)168
bridge circuit for feeding several loads, 1491
constant-voltage, for transistor circuits, 2797
d.c., stabilized, using glow-discharge regulator tubes, 231
h.v., corona-stabilized, for proportional counters, 1803, low-current, using transistor oscillator, 833
small, effective current and efficiency of, 2799
stabilized, 552, for electrometer valves, 1133
stabilized rectifier unit for 5 kV, 50 mA, 2800
for transmitters, 2454
vibrators and vibrator power packs, recent developments in, 228
50–300-V, 2152
0·5–3-kV, using r.f. oscillator, 1134
25-kV, using r.f. oscillators, 553
600-VA, thyratron inverter circuit for, 1490
Public address systems, portable equipment for, 1899
for power stations, 615, 3470
Pulses, amplitude spectrum of, and pulse technology, 3105
coding and decoding by passive networks, 2441
sine-squared, for television testing, 3377

***Q* factor**, measurement of, 775
chart for use in, 464
frequency-sweep method for cavity resonators, 465
meter, correction abac for errors due to valve-voltmeter loading, 783
Quadripoles. See Networks, quadripole.
Quantum theory, of fields, mathematical aspects of, 1289, 1290, 2620
relation to theories of gravitation and electromagnetism, 3570
soluble problem in energy bands, 391
Quartz, crystals, h.f., for filter networks, 3552
internal friction of, 2349
operational characteristics of, 140
resonators, design and applications of, 441, harmonic oscillations of, 1619, impedance meters for, 2390, measurement of parameters of, 3670, mechanical loading for adjusting frequency of, 966, in parallel-resonance circuits, activity measurement for, 1273, tuning-fork type, for 1–20 kc/s, 2267, variation of resonance frequency with pressure up to 5000 atm, 442, 100 kc/s, high-stability, 1083
fused, for ultrasonic delay lines, 3637
variation of conductivity of, 1378

Radar, (See also Aerials; Lenses; Navigation aids)
applications, measurement of velocity of projectiles, 174
back-scatter from cylindrical wires, 36
and detection of icebergs, etc., 2673
displays, c.r. tube, quality factor for, 2317
p.p.i., moving-target indication systems, 2672, television unit for, 2001
remote, Decca link equipment for, 2005
special type of p.m. transmission system for, 'Durchmusterung', 2002
echoes, and lightning, 107
from precipitation, the 'melting band', cross-polarization of, 1364, 'melting-band' phenomena in, 2314
from rain, 2994, from non-freezing clouds, 2004, at Sydney, New South Wales, 3312
echoing-area measurements on models, use of dielectric lenses in, 1366
equipment, for moving-target indication, measurements on, 1446, at Orly, 3316
marine, 3-cm/10-cm equipment for merchant ships, 730
omnidirectional reflector system for, 1684
optimum pulse-integration angle and system sensitivity of, 2671
panoramic, cinematographic recording equipment for, 2007
port equipment, Decca, demonstrations at Hamburg and Bremen, 1360

World Radio History

Radar, port equipment, installations at Boston, Long Beach, New York and Liverpool, **1685**
pulsed, magnetic modulators for, **2992**
search, for civil aircraft, **109**
training apparatus for air-traffic control, **1368, 3319**
Radiation, (See also Aerials)
detectors, phosphor-photocell, Type AN/PDR-18, **1103**
Radio astronomy, See Astronomy, radio.
communication, international organization of, and world problem of frequency allocation, **2785**
engineering, sources of information on, **2192**
progress, I.R.E. review for 1952, **2527**
station, at Lüchow, West Germany, organization and installations of, **2444**
technology, applications of theory of numbers in, **3346**
Radio links, (See also Communication systems; Radiotelephony; Relay systems; Television)
cm-λ, Manchester/Edinburgh, travelling-wave valves in, **2829**
directional, in Western Germany, and equipment for, **2140**
f.m., microwave, multichannel, design of, **217,** multichannel, wide-band circuit technique for, **220**
for telephony, experimental equipment for 420–470-Mc/s and 860–960-Mc/s, **3412**
km-λ, intelligibility in, and mean level of atmospherics, **105**
microwave, measurement techniques and components for, **219**
4-kMc/s, path attenuation measurement for, **1091**
multichannel, u.h.f., between Mestre and Trieste, **3109**
s.w., s.s.b. multichannel operation of, **2144, 2175, 2425**
in U.S.A., survey of, **545**
u.s.w., graphs for design calculations, **2118**
Radiosonde, automatic radar system operated by British Meteorological Office, **3675**
improved, **497**
without responder, pulse observations of wind by, **2993**
Radiotelegraphy, (See also Communication systems)
percentage of error signals received, recorder for, **3696**
smallest permissible frequency separation between transmissions, **549**
Radiotelephony, (See also Communication systems; Radio links; Relay systems)
beam link, f.m., u.s.w., multipath distortion in, **218**
beam-system, p.ph.m., channel separation in, **1788,** 12- and 24-channel, **822**
Israel intercity, f.m., 250-Mc/s, **2442**
mobile, transmission problems of, **1486, 3417**
multichannel equipment for Eindhoven–Tilburg link, **546**
new terminals of Centro Radio Nazionale P.T., **2793**
Rhine ship service, propagation tests for, **542**
s.s.b., 4–23-Mc/s, 4-channel equipment for, **541**
for trains, German investigations on, **225**
Reactors, saturable, with inductive d.c. load, steady-state operation of, **3527**
as reference source for magnetic amplifiers, **2237**
Receivers, (See also Radar; Television)
all-wave, 100-kc/s–30-Mc/s, Type-E 103AW/4, **207**
a.m., noise eliminator for, **2132**
broadcasting, a.m./f.m., for comparing transmissions in the range 87·5–95 Mc/s, **2121,** new trends in design of, **2427,** using new valves, **204**
u.s.w., development of circuit and valves for, **2428**
VVB-RFT, at the Leipzig Fair, **810**
communication, band-spreading, method for, **812**
easily demountable, **525**
s.w., superheterodyne, design of, **3697**
definitions of terms, 52 IRE 17S1 standard on, **811**
d.f., matched-channel, phase and gain stabilization in, **2320**
long-wave, stable, for space-wave measurements, **2123**
miniature, for Palais de Chaillot N.A.T.O. translation service, **2794**
monitoring, with automatic frequency-sweep device, **2122**
for r.f. noise measurements, **3402**
space-diversity, a.f. combining system for, **2426**
subcarrier, 1-Mc/s, for f.m. multiplex system, **3099**
superheterodyne, cm-wave, noise factor of, **1790**
with crystal mixer, sensitivity and noise factor of, **2127**
dust-core-tuned, design of, **526**
impulse response of, operational analysis of, **1115**
microphony in oscillators in, **814**
radar, second-detector signal/noise improvement in, **527**
tracking methods for, **2126**
using transistors, **(A)3403**
s.w., independent-sideband, **2425**
signal/noise ratio of, dependence on input voltage of, **2125**
and transmitters, for citizens' radio, **2437**
v.h.f., noise performance of, **1789**
Reception, (See also Field strength; Television; Wave propagation, e.m.)
decametre-wave, Paris/New York, deterioration of since Aug. 1950, **202**
of frequency-shift signals from s.w. transmitters, **3399**
of pulsed carrier waves in noise, statistical criteria for, **2782, 2783**
of signals in noise, nonlinear filters for, **206**
optimum filters for, **205**
of sine wave in Gaussian noise, **2429**
of 1–10-c/s signals in noise, commutator device for improvement of, **2784**
Recorders, (See also Sound recorders)
frequency, electronic, automatically calibrated, 10–130-c/s, **2377**
ionosphere, automatic, for range 0·6–25 Mc/s, **3356**
panoramic, 16-kW, 1–20-Mc/s, **3052**
Recorders, ionosphere, 50-kc/s–1-Mc/s, **1998**
1–20-Mc/s, 1-kW, Netherlands P.T.T., **2989**
keep-alive arrangement using 10-c/s multivibrator, **473**
Numerograph, for digital computer, **1726**
pulse, with timing trace, **2379**
tone-pitch, for phonetics research, **1226**
Recording, (See also Sound recording)
field-strength, 'fixed-level' method of, **2065**
Rectification, (See also Semiconductors)
thermal, in semiconductors, **3015**
Rectifiers, (See also Valves, crystal)
barrier-layer, barrier height in, **1852**
theory of, **2038**
crystal, CdS, properties of, **3136**
Cu_2O, zero-bias resistance of, temperature dependence of, **3345**
Cu_2O, CuS and Se, developments in, **2154**
electrolytic, Al-Al_2O_3, impedance of, **2801**
Ge, **2698**
contact-p.d. of, changes of during forming, **3260**
diffusion theory of, effect of high-field mobility in, **2697**
forming of, investigations of, **2032**
p-n-junction, medium-power, **835,** power-unit, **834,** temperature dependence of backward current in, **423**
point-contact, reverse characteristics of, **1715**
and transistor, theory of, **2821**
harmonic-insensitive, for a.c. measurements, **3662**
Hg-arc, Nevitron, **836**
Mg-CuS, hermetically sealed, **2153**
output-voltage control by transductors, **839**
point-contact, effect of minority carriers on breakdown of, **437**
power-law, output signal/noise ratio of, **3405**
Se, blocking mechanism of, **2699**
capacitance of, **1802**
electron multiplication in reverse operation of, **2350**
temperature variation of characteristics of, **1389**
40-V, development of, **2457**
Si, point-contact, effect of heat treatment on, **1714**
solid, dynamical theory of, **3630, 3631**
TiO_2-film, **229**
valve, high-power, h.v., **2155**
Reflection, (See also Sound; Wave propagation, e.m.; Waves)
coefficient, of stratified medium, use of calculus of variations for determination of, **1314**
of transmission systems, determination of, ratio meter for, **466**
of e.m. waves, from regions of refractive-index gradient in atmosphere, **1780**
from rough sea surface, **1106**
of microwaves, from ground and water surfaces, **1787**
by metal-plate structures, **389**
of sound or e.m. waves from point source at plane boundary, **2540**
Reflectometer, directional-coupler, for measurements in s.w. range, **477**
waveguide, wide-band, recording, **468**
Refractive index, of air/water-vapour mixtures at dm λ, **1642**
r.f., of atmosphere, constants in formula for, **1990, 3287,** measurement of variations of, **1085,** rapid variations in, **431,** slide-rule computation of, **1014**
vertical and horizontal distribution of gradient of in troposphere over U.S.A., **1991**
of water vapour, air, O_2, N_2, H_2, D_2 and He at 9·2 kMc/s, **2062**
Regulators, alternating-voltage, electromechanical, **3726**
current and voltage, using reference standard, **3725**
direct-voltage, electronic, **1804**
for kilovolt range, **838**
variable, using cold-cathode triode, **554, (D)1805**
speed, electronic, theory of, **1451**
voltage, using nonlinear elements, **230**
Relay systems, (See also Communication systems; Radio links; Radiotelephony; Television)
microwave, in Europe, North Africa, Near East and Australia, **3108**
multichannel, Australian, **3110**
TD-2, station equipment for, **216**
u.h.f., planning of, **1126**
Research, radio, in British Commonwealth, **2528**
on radio and electronics, in Russia, **2525**
on tropospheric e.m. wave propagation, at N.B.S., **2768**
Resistance, a.c., realization of, **3493**
h.f., apparent, of conducting strip parallel to conducting plane, **80**
Resistivity, of Bi, variation in magnetic field of, and Corbino effect, **1710**
of cold-worked metals and alloys, effect of temperature of deformation on, **1027**
of metals, at high current density, with pulsed operation, **1377**
in magnetic field, theory of, **378**
of refractory oxides at 600–1500°C, **2684**
variation in magnetic field, mechanism of, **377**
Resistors, borocarbon, characteristics of, **340**
carbon-film, temperature coefficient of, **1921**
for 200°C, production of, **947**
coated-glass, E-C, **1253**
fixed, developments in, review of, **946**
nonlinear, shaping of characteristics of, **341**
printed, production control of, **47**
Russian notation for value of, **2927**
standard, a.c., **3360**
Au-Cr, **772**
thin-film, disk-type, for r.f. micropotentiometer, **3525**
10^8–$10^{11}\Omega$, measurement of, **3056**
$>10^{12}\Omega$, methods of measurement of, **459**

World Radio History

Resonance curves, simple explanation of, **675**
Resonators, (See also Piezoelectric crystals; Quartz)
acoustic, Helmholtz, in B.B.C. studio at Swansea, **309**
spherical, effect of viscous dissipation in, **1564, (C)3172**
tubular and hollow-brick types, absorption by **310**
cavity, coupled, resonance frequencies for, **1621**
containing crystals, e.m. oscillations in, **1315, 1623**
operating in degenerate modes, perturbation effects in, **360**
double-loop-coupled, analysis for, **967**
with finite wall conductivity, natural e.m. oscillations in, **67**
influence of surface finish and atmospheric conditions on, **2932**
lossless, with hole excitation e.m. field in, **2268**
microwave, interaction of modes in, **2933**
Q measurement for, frequency-sweep method of, **465**
dielectric-cylinder, high-permittivity, quasi-degenerate modes in, **1942**
magnetostrictive, ferrite, and applications, **2229**
vibrating-wire, high-*Q*, **3561**
Response, of linear time-dependent systems to white noise, **2856**

Sampling, sequential, for attributes, theory of, **2715**
Scattering, (See also Sound; Wave propagation, e.m.; Waves)
of e.m. or sound waves, by grating, **695**
by irregular surface, **2968, 2969**
Screening, of electrical equipment, design of mesh networks for, **2796**
of test rooms and instruments, **3116**
Sealing, by optical polishing, **141**
Seals, enamel, for mica windows in G-M tubes, **3638**
glass/kovar, hermetic, **2711**
glass/metal, fundamentals of, **2712**
high-conductivity, **142**
hermetic, **2356**
Semiconductors, adiabatic Hall effect in, **3018**
alternative theories of, **78**
anthracene single crystals, electronic conductivity of, **3016**
BaO, diffusion of Ba in, **432**
BaO single crystals, Hall effect in, **129**
boron, electrical and optical properties of, **1696, 2031**
CdS, rectifier properties of, **745**
CdS single crystals, contact noise in, **3023**
ceramic, 'Caslode', for microwave power absorption, **2029**
conduction in, influence of state of division on type of, **2686**
contact noise in, **2334, 3022**
contact phenomena in, theory of, **2687**
copper sulphides, electrical and optical properties of, **1028**
Cu_2O, high temperature conductivity measurements on, **1386**
low-temperature conductivity of, dependence on oxygen pressure during annealing, **1385, 1387**
optical absorption in, effect of lattice defects on, **1384**
production methods for stability of, **1383**
properties of, **1701**
thermoelectric measurements on at high temperatures, **3613**
current carriers in, added, transport of, **3611**
determination of effective mass of, **1381**
current noise in, **748**
re-examination of Bernamont's data on, **747**
cyclotron resonances, magnetoresistance and Brillouin zones in, **3017**
diffusion constant and electron and hole mobility in, verification of relation between, **1305**
drift mobility in, measurement of, **1379**
effect of electron surface state on optical properties of, **1304**
electron spin in, **1960**
energy states of impurity carriers in, **1382**
ferrites, magnetodynamics of, **1029**
GaAs and InAs, preparation and properties of, **3325**
Ge, acceptors produced by quenching of, **1407**
contact resistance of, **1030**
Cu as acceptor element in, **119**
effect of magnetic field on noise in, **2695**
effective mass and relaxation time of conduction electrons in, **2330**
elasticity and thermal expansion of, **2348**
electron mobility in, **425**
energy-band structure of, **1699**
filaments, shot noise in, **2035**
grain-boundary barriers in, **1406**
Hall effect in, three applications of, **1930**
heat-treated, infrared absorption of, **2678**
high-field mobility in, with dominant impurity scattering, **3328**
large-area contacts on, properties of, **118**
lattice defects, heat-treatment-induced, **1697,** activation energy of, **742**
lifetime of carriers in, **740, 741**
microwave measurements on, **3618**
n-type, low-temperature Hall curve for, **426,** single-crystal, effect of heat treatment on, **2333**
noise in, **122**
observations of dislocations in boundaries, **2693**
p-type, contact properties of, **117,** infrared absorption bands of, **424**
photomagnetoelectric effect in measurements of, **2016**
plastic deformability at relatively high temperatures, **2033**
p-n junction, electronic states under strong applied fields, **736,** fused-impurity, impurity diffusion and space-charge layers in, **3020,** pressure-welded, **2034,** production by diffusion, **739**
production, properties and applications of, **1405**
radiative transitions in, **2331**
Semiconductors, Ge, recombination rate in, determination of, **2692**
relation between charge-carrier and pulse drift mobilities in, **3617**
solute distribution in, **3343**
space-charge-limited hole current for high applied voltages, **3329**
surface forming of, **3330**
surface properties of, **1698**
temperature dependence of drift mobility in Ge, **2332**
thermal conversion of, impurity effects in, **116**
thin films, Hall constant and resistivity of, **3615**
ultrasonic-attenuation measurements in, **2694**
uses in telecommunications technique, **1850**
Ge single crystals, apparatus for production of, **2707,** optical constants of, **3344,** preparation of, **744, (C)1408**
Ge and Si, diffusion of Li into, **3616**
electron traps in, **2691**
field dependence of mobility in, **3326**
physical properties of, **738**
plastic deformation of, **1403, 1404**
solubility in Ga and In, **3033**
Ge, Si and Hf, isotopic constitution of, **3341**
haematite, crystal structure and antiferromagnetism in, **1311**
thermomagnetic properties of, **2705**
intermetallic compounds, CdSb, properties of, **3619**
InSb, magnetoresistance effect in, **2696**
InSb, GaSb and AlSb, **2688**
K-Sb, Cs-Sb K-In and Cs-In systems, properties of, **2030**
iron-oxide agglomerates, conduction mechanism in, **114**
iron-oxide-mixtures, lattice defects and Debye r.f. absorption in, **2328, (C)3612**
magnetoresistance of, theory of, **2329**
metal contact with, theory of, **379**
micromanipulator for location of point contacts on, **2999**
mixed *n*- and *p*-type, theory of, **2028**
molybdenite, electrical properties of, **2708**
oxides, variations of lattice parameters of, **115**
PbS, band structure, investigation by cellular method, **2037**
sintered, conductivity and Hall coefficient of, **120**
transistor action and related phenomena in, **2036**
PbS, PbSe and PbTe, intrinsic conduction in, **1388**
PbTe, investigation of transistor action in, **1409**
photomagnetoelectric effect in, theory of, **2015**
p-n junctions, production of, by variation of crystal-growth rate, **743**
revealed by electrolytic etching, **3332**
theory of noise in, **871**
porous, conductivity of, **737**
properties and applications of, **427, 1703**
recombination of holes and electrons in, statistics of, **420**
rectifying pairs, relaxation processes in, **3620**
resistance/temperature characteristics of, measurement of, **3614**
Sb_2S_3 and Bi_2S_3, electrical properties of, **3019**
Se, amorphous and hexagonal, optical absorption and reflection of, **2019**
multicrystal, electrical properties of, **2690**
shot noise in, calculation of, **2040**
Si, effective mass of conduction electrons, **421**
energy-band structure in, **3327**
n-type, powdered, electron-spin resonance absorption in, **3342**
p-type, thermoelectric constant of, **82, 2335**
resistivity and thermionic emission of, **3333**
single-crystal rods, **422**
space-charge-limited emission in, **3324**
'swept intrinsic', field distribution in, **2689**
Te-film, effect of electric field on conductance of, **1695**
Te single crystals, infrared transmission of, **417**
technical vocabulary for, French, **1702**
thermal rectification effect in, **3015**
thermo- and galvano-magnetic coefficients for, **1380**
various, transistor properties of, **121**
ZnO, photodielectric effect, ferroelectricity and thermoluminescence of under ultraviolet excitation, **3005**
sputtered layers, effect of dissolved oxygen on electrical conductivity of, **1031**
study of lattice defects by r.f. spectroscopy, **1700**
Servomechanisms, (See also Control systems)
a.c., compensation networks for, graphical synthesis of, **2448**
effects of carrier shifts on derivative networks for, **2452**
airborne, discriminators for, **3422**
application of nonlinear techniques in, **3111**
carrier-frequency, synthesis of compensation networks for, **3115**
closed-loop, reduction of forced dynamic error in, **3423**
comparators for, **3113**
using compensated magnetic amplifier, **3114**
conditionally stable feedback systems for, design of, **2453**
design of, analogue computer for, **1055**
using filtered oscillators, stability of, **2449**
for heterodyne-oscillator drive, **2378**
instrument, damper-stabilized, design of, **549**
linear, solution by means of equivalent network, **550**
multiple, stability of, **227**
nonlinear, **831**
with filters, transients in, **1130**
transient response of, **3112**
with nonlinear friction, operating modes of, **3421**
remote-position-control, hydraulic, and analogue computer for, **1054**
sampling, application of pulse transfer function to, **1131**
second-order, **3420**
saturating, phase-plane analysis of, **2447**

World Radio History

Servomechanisms, survey of, **830**
synthesis of by root locations, **(A)2150**
theory of, formula for integral occurring in, **832**
transient performance calculation from db/log *f* plots, **3721**
use of rotary amplifiers in, **2451**
variable-carrier-frequency, stabilization of, **551**
with variable elements, stability of, **3723**
theory of, **1800**
Signal generators, (See also Generators; Oscillators; Test equipment)
covering range 20–1200 Mc/s, **1084**
spurious f.m. in, **3562**
giving stepped signal corresponding to graded greys, for television testing, **565**
two-range, **485**
Signal/noise ratio, i.f., decrease of when increasing i.f. bandwidth, using square-law or linear detector, **3404**
for various modulation systems, **828**
Signals, analytical, with limited spectra, **2137**
and synchronization of amplitude-limited oscillators, **1943**
and linear transmission operators, analysis of, **3703**
pulse, with thermal noise, optimum clipping for, **2781**
Skin effect, anomalous, in metals, at low temperatures, **1303**
in conducting materials, chart for, **435**
Slide rule, vector, **2714**
Solar activity, correlation with atmospheric pressure fluctuations, **1323**
correlation with geomagnetic activity, **1011**
correlation with geophysical phenomena, **1983**
——**corona,** and geomagnetism, **1326**
observations at eclipse, 25th Feb. 1952, **716**
——**flares,** and magnetic storms, **3276**
——**radiation,** effects of, in upper atmosphere, **1321**
r.f., from corona, at 10 cm–10 m λ, **3277**
dm-λ, asymmetry of, **3273**
'enhanced', and plasma-oscillation theory, **1322**
inadequacy of thermal theories of, **1980**
m-λ, origin and characteristics of, **2971**
outbursts at 8·5-mm λ, **93**
during solar eclipse, 28th April 1949, **3402**
during solar eclipses, 1st Sept. 1951 and 25th Feb. 1952, **94**
from sunspots, directivity of, analysis of, **1981**
Soldering, by dip method, for radio and television receivers, **2710**
Sound (See also Absorption; Acoustics; Diffraction; Reflection; Wave propagation; Waves)
absorbers, membrane-type, and application in broadcasting studios, **924**
attenuation by ceilings, measurement with sinusoidal excitation, **2871**
effects, for radio plays, electroacoustic production of, **3177**
field, near circular transducer, **913**
of disk, effect of finite circular baffle on, **1555**
of infinitely long vibrating cylinder, **1554**
of plane waves, and steady streaming, **1551**
of rectangular piston membrane, **1877**
second-order, energy/intensity relations in, **2194**
and steady rotational flow, **1552, (C)3166**
between two infinite walls, due to piston source, **1876**
insulation, by means of rubber and steel springs, **608**
measurement of, storage methods of, **3464**
musical, relations between electrical and mechanical production of, **3461**
particle-velocity measurements in liquids with Rayleigh disk, **305**
pressure, multiple-Rayleigh-disk arrangement for measurement of, **1228**
propagation, effect of meteorological conditions on, review of, **2533**
in gas, **1875**
in granular media, **923**
in labyrinth, application of variational principle in theory of, **2857**
in liquid-filled cylinder with surrounding elastic fluid, **2858**
in rectangular tube, attenuation of, **2537**
in stratified region of troposphere, theory of echoes in, **1880**
in tubes with obstacles or discontinuities, **2193**
radiation pressure, physics of, **1878**
of plane waves at oblique incidence, **6**
radiators, absorption surface of, **1220**
directivity and amplitude distribution of, **1221**
reception, directional, review of methods of, **1574**
underwater, thermal-noise limit of, **106**
reflection, from ocean layers with temperature change, **3463**
of spherical pulse by absorbent infinite plane, **914**
from surfaces with periodic structure, **1895**
rotation of plane of polarization by acoustic gyrator, **1874, 2532**
scattering from sea surface, **2541**
signal-distribution arrangements at South Bank site, London, **23**
source-intensity, in liquids, dependence on absorption coefficient, **2543**
measurement of, **2536**
theory of single-channel transmission, **1229, 1890, 2869**
transmission through partitions, investigation using small-scale models, **609**
velocity, in air, measurement of, at 1 kc/s, **1566,** at 13·5 kc/s, **605**
errors in indirect measurements of, **916**
in liquids, temperature dependence of, measurement of, **1224**
measurement of, properties of water-filled tubes for, **2866**
——**recorders,** magnetic, **2551**
interference effects in recording heads of, **2876**
print-through effect in, **1901**
tape field with ideal and with wide-gap pickup head, **1575**
——**recording,** disk, binaural, two-band system, **2550**
calibration by light-pattern measurements, **2875**
Sound recording, film, using electro-optic crystal, **2209**
magnetic, in cinema-film production, **21**
effect of head and tape constants in, **2555**
on magnastripe film, **2205,** film production for, **2204, 2206, 2207, 2208,** wear of magnetic heads in, **2203**
standardization of technique of, **22**
stereophonic, **1902**
studies on, **3471**
tapes for, high-output, performance of, **1576,** improved, **2553,** measurement of surface induction of, **2552,** mechanical properties of and quality of recording, **20,** noise tests on, **2877**
very-long-period, continuous, apparatus for, **3180**
and reproduction, 53 IRE 19S1 standard on methods of noise measurement in, **1900**
——**reproducers,** disk, pickups for, lateral mechanical impedance of, **3181**
——**reproduction,** disk, measurement of distortion in, **2736**
needle wear in, **(A)316**
electronic automatic volume compression in, **965**
high-quality, circuit and auditorium requirements for, **611**
magnetic, analysis of, **2554**
stereophonic, **1902**
Spectrometer, high-speed, infrared, **1758**
radio. See Analysers, frequency-spectrum.
Spectroscopy, microwave, coaxial cell for, **1317**
applied to determination of nuclear moments, **1008**
at 1–2-mm λ, **2623**
Speech intelligibility, effect of frequency and amplitude distortion on, **10**
perception of, analysis of processes in, **920**
sounds, three-dimensional models for, **11**
typo-sonograph for, **1568**
synthetic, investigation of consonant sounds, **919**
Stability, of control systems, **1489**
criterion, general, for networks, **2231**
frequency, of linear oscillator, effect of noise on, **362**
Stabilization, frequency, in microwave range, **46**
of nonlinear feedback control systems, **1761**
of variable-carrier-frequency servomechanisms, **551**
voltage, corona discharge tubes for, **1136, (D)2803**
improved, with voltage-regulator tube, **837**
review of, **2458**
with series valve control, **2802**
Stabilizers. See Regulators.
Standard frequency transmissions, (See also Frequency standard)
Rugby, **1732**
24-hour service, **1423**
and time signals, WWV, automatic announcing system for, **1731**
world-wide reception of WWV and WWVH, **522**
Standardization, of symbols and circuit diagrams, **3492**
of telecommunications equipment in France, **2526**
Standards, (See also Television)
resistance, absolute determination of ohm, **1426**
and units, electrical-measurement, review of, **1059**
52 IRE 17S1, definitions of terms on receivers, **811**
53 IRE 7S1, on noise measurement, **3055**
53 IRE 11S1, definitions of modulation terms, **2438**
53 IRE 19S1, on noise measurement in sound recording and reproduction, **1900**
53 IRE 22S1, definition of colour terms for television, **1817**
Sun, density and velocity of material in, estimate of, **1982**
distribution of radio brightness at 9·35 kMc/s on, **3272**
research at Kodaikanal observatory on, **392**
Sunspot cycle, 22-year period of, **2304**
Sunspots, effect on geomagnetic activity, **2642**
flares and filaments, observed at Stockholm in 1950 and 1951, **715**
and geomagnetic storms, **2641**
interrelation of numbers and ionosphere critical frequencies for different sunspot cycles, **1350**
magnetic field of, **2303**
periodicity of number variations, **3595**
physical conditions in, deduction of, from spectral data, **1324, 1669**
provisional numbers, April–June 1952, **395,** July–Sept. 1952, **1325,** Oct.–Dec. 1952, **1984,** Jan.–March 1953, **3275**
relative numbers, final, for 1951, **394**
Switches, electronic, using cold-cathode gas-discharge tubes, **288**
in communication engineering, **48**
using multivibrator, **654**
triode, **343**
multichannel, for microwave circuits, **1252**
t.r. and a.t.r., C.F.T.H., for 3-cm radar equipment, **588**
waveguide, rotary, **2241**
Synchronization, (See also Television)
a.f.c., theory of, **3214, (C)3524**
for c.r.o. display of variable voltages, **339**
of *LC* oscillators, **2940**
of pulsed high-energy ion beams, **1448**

Telecommunications, in civil aviation, **3419**
equipment, standardization of, in France, **2526**
in Nyasaland, **1119**
Telecontrol, of broadcasting transmitters, **2762, 2763**
of clocks, by pulses at 1-sec intervals, **1421**
Telegraphy, frequency-shift, on carrier-current telephone lines, **2434**
teleprinter, distortion in, c.r.o. measurement of, **3408**
technical progress in, **2138**

World Radio History

Telemetry, high-speed system of, **3674**
multiplex teletype system of, **1097**
pulsed light-beam system for e.s. accelerator, **794**
review of methods of, **1762**
wire system for transmitter circuits, **2762**, **2763**
10-channel pulse-code system of, **498**
23-channel p.p.m. system for rockets, **726**, **2404**
Telephone earpieces, suitability for measurements on f.m. tones, **312**
Telephony, (See also Carrier-current systems)
circuits, cable, uniform, determination of primary parameters of, **2556**
multichannel systems, intermodulation noise in, **827**
short-range, ultrasonic system of, **1885**
Television, (See also Aerials; Interference)
adaptation of eye in relation to optics of, **563**
amplifiers, h.f. and i.f., effects of feedback in, **1954**, gain and bandwidth of, **1639**, noise problems of, **1640**
i.f., with bifilar-wound coils, **3735**
with optimum transient response, **3133**
for pickup tube, fluctuation noise in, **1837**
wide-band, factors in design of, **1838**
applications of, industrial and professional, **1844**
in industry, research and education, **1512**, **2815**
to operative-surgery demonstration, **1845**
bandwidth reduction in, **1825**
signal compression by recoding, **1154**
techniques for, **1824**, **3731**
cameras, auxiliary equipment for, **1165**
B.B.C., with optical view-finder, **856**
in cinematograph-film making, **1830**
conductron, **3128**
effect of tube characteristics and other factors on design of, **854**
image-iconoscope, improvements in, **2167**, **3733**, use of electron multipliers in, **855**
image-orthicon target, French origin of, **2808**
with remote control of lens selection and focus, **2164**
signal generation in, **1829**, **3433**
small, for high-speed scanning, **853**
storage-type, signal generation in, **1828**
vidicon, performance of, **249**
5 : 1 zoom lens for, **849**
colour, channel width for, **2805**
colorimetry in, **3123**
compatible systems of, **1815**, colorimetric analysis of, **1816**, principles and development of, **3428**, R.C.A., colorimetric analysis of, **3429**
constant-luminance system, gamma correction in, **238**
definitions of terms in, approved, U.S., **561**, I.R.E. standard, **1817**
developments in U.S.A., **2162**
dot-sequential, band-shared systems, improvements in, **(A)240**
flying-spot signal generator, **2807**
frame synchronization for, **236**
fundamental aspects of, **1814**
kinescopes, shadow-mask, 3-gun, **575**
large-screen, eidophor system of, **2474**
methods and colorimetric principles of, **1813**
N.T.S.C. compatible system, effects of noise on, **2467**, field tests of, revised specifications for, **2466**, field tests of, signal generation for, **1822**, **2465**, optimum utilization of r.f. channel for, **3431**, receiver for, **1501**, **3130**, subcarrier system, mathematical treatment of **3124**, subjective tests of synchronization signal for, **3427**, synchronous demodulator for, **253**, **3129**, **3436**
phosphor screens for c.r. tubes for, preparation of, **3440**
rotating-screen c.r. tube for reproduction of, **3740**
single- or multi-gun chromatron, **3131**
subjective and objective aspects of colour rendering in, **1818**
survey of, **239**
synchronization in, **2464**
visual problems in, **(AD)1493**
combining filter for common-aerial vision and sound transmission, **1162**
as communication problem, **1820**
control rooms, planning of, **863**
converter, from 405-line to 625-line standard, **2469**
from 819-line to 405-line standard, **3432**
Coronation transmissions, Hinsbeck relay station for, **3425**
technical arrangements for, **2804**
to Western Europe, **3118**, radio and cable network for, **2461**
c.r. tubes, with bent neck, **3737**
characteristics of, **2171**
magnetic deflection system for, ferroxdure magnets in, **862**, field plotting in design of yokes, **256**, with internal pole pieces, **257**, using permanent magnets, **573**
design factors of, **1540**
manufacturing methods for, **1870**
phosphors for, **1869**
steel, development of, **3132**
univoltage e.s. lens for, **1541**
and valves, for television receivers, **1521**
experimental equipment of Radio-Basel, **1509**
field-strength surveys for, at u.h.f., **523**
for 500-W transmitter on the Dôle, Switzerland, **246**, **2166**
frequency allocations for France and dependencies, **1827**
in Great Britain, **3732**
history of, **848**
in Italy, activities of study centre for, **3120**
limited-spectrum signals, effects of amplitude and phase distortion on, **1177**
Television, line standard, optimum, as dependent on size of receiving screen, **844**
line timebase, output stages with booster circuit for, **2478**
single-valve, **2814**
links, British network, **242**
cable, Birmingham/Holme-Moss, frequency-translating terminal equipment for, **1149**, Birmingham/Manchester/Holme-Moss, **1147**, in Germany, **2436**, L3, terminal equipment for, **3424**, London/Birmingham, delay equalization of, **1148**, for outside broadcasts, **1145**
cable and radio, in United Kingdom, **1142**
Hamburg/Cologne/Frankfurt, **3426**
London/Birmingham, u.h.f. filters and switches for, **951**
microwave, high-power, mobile, **1159**, Louisville/Nashville, U.S.A., **2463**, portable equipment for, **1158**
nonlinearity in, measurement methods for, **1064**
temporary, for outside broadcasting, **1143**
u.s.w., between Berlin and Hamburg, **1810**
wire and microwave, for 1952 National Political Conventions, **3134**
3·6–5·0-kMc/s, coaxial-line v.m. oscillator valve for, **1211**
mobile equipment of U.S. Army Signal Corps, **1821**
outside broadcasts, in Northern England, **560**
technical arrangements for, **1144**
picture projection with 60-sec delay, **241**, **1155**
picture quality, distortion due to echoes, **3441**
relation of to transient response, **3745**
picture signals, energy spectrum of, **234**
present development of, **237**
programmes, engineering technique of, **842**, **843**
problems of sound in, **846**
projection, receivers, problems of, **251**
for theatres, c.r.-tube system for, **1835**, design of, **2811**, eidophor system of, **2473**, equipment for, **562**, h.v. generators for, **569**, precision synchronizing system for, **1812**, problems of, **1168**, **(C)2170**, **2472**
receivers, a.c./d.c., and valves for, **1503**
accurately synchronized, incorrect interlacing in, **1498**
adaptation of French 819-line to American 525-line standard, **2471**
a.f.c. systems for, design of, **3119**, testing of, **570**
a.g.c. systems for, **250**, **1832**, **1833**
blanking circuit for, **572**
British-type, **1495**
constant-input-impedance second detector for, **254**
converter for, **2189**, u.h.f., **861**, 427/45-Mc/s, for Television Society's transmissions, **2809**, **(C)3434**
d.c. level restoration in, **1500**
deflector-coil construction for, **574**
effects due to cathode-interface impedance in, **2505**
faulty interlacing in, **(D)255**
frame-deflection circuit with voltage-dependent resistor, **3741**
frame-scanning circuits for wide-angle c.r. tubes, **1507**
gamma-control circuit using crystal diodes, **1826**
Ge diodes in, **1505**, as video detectors in, **2475**
grounded-electrode valve circuits for, analysis of, **1632**
input stages of, comparative survey of, **1167**
with intercarrier sound channel, **857**, **3734**
mass-production, **3739**, factors affecting design of, **1496**
mechanized dip-soldering of, **2710**
performance in presence of interference, **1511**
push-pull amplifiers in video output circuits of, **3743**
reactive timebases for, **860**
reduction of radiation from, **2476**
scanning defects, reduction of, **3439**
Se and Cu_2O rectifiers in, **1502**
slow-acting synchronization circuits in, operation of, **3736**
sound, critical capacitance coupling in, **1831**
superheterodyne, design of, **1504**
synchronizing circuit, flywheel, **1499**, **2479**, **2480**, **3738**, using ECL 80 and EQ 80 valves, **2168**
synchronizing-signal clipper with noise immunity, **252**
transistor circuits for, **2813**
u.h.f. tuner, **1166**, coaxial-cavity, **1952**, design and performance of, **571**, 3-cavity, **1506**
v.h.f.-u.h.f. tuners for, factors affecting design of, **3438**
v.h.f./u.h.f., design of, **1497**
Wireless World design, modernization of, **2810**
625- and 525-line, tests on, **2397**
reception, in fringe areas, community aerials for, **859**
ionospheric influences in, **1176**
modulation distortion in, **260**
storage and picture-difference methods in, **2163**
recording, of cinematograph films, B.B.C. equipment for, **851**
on cinematograph film, and reproduction from, **3125**
various methods of, **847**, **2468**
retransmission equipment, Ekco, **258**
scanner for 35-mm film, **852**
scanning-current linearization by negative feedback, **(A)248**
service area of Wenvoe 50-kW transmitter, **1510**
signal-distribution arrangements at South Bank site, London, **23**
standards and channels in S. America, **1494**
stations, B.B.C., **1171**, Kirk o' Shotts and Wenvoe, **244**
'booster', for fringe areas, **1811**
Montreal and Toronto, Canada, **1170**
N.W.D.R., **2148**
100-kW, Sutton Coldfield, **1508**
stereoscopic, practicability of, **2806**

World Radio History

Television, studios, B.B.C., lighting techniques in, 865
discharge lamps for, 866
equipment testing with variable-phase synchronizing pulses, 3373
illumination of, 1164
lighting equipment for, 864
at 1951 Radio Exhibition, London, 564
synchronization technique in, 1153, (C)2161
systems, noise measurements on, 868
square-wave testing of, 1754
transient testing of, 1065, using sine-squared pulses, 3377
test equipment, 1823, 2396
for comparison of line standards, 1753
grey-scale generator for, 565
wide-band frequency-sweep generator for tests on, 486
6 waveform generator and display unit for, 1087
test-pattern transmission, monoscope for, 850
transmitters, in Great Britain, selection and testing of sites for, 1172
high- and low-level modulation for, comparison of, 567, 568, (D)1163
high-power, Holme Moss, design of, 1161
mobile, B.B.C., 3127, hinged mast for, 1160
Wenvoe, Glamorgan, 3126
wide-band amplifiers for, 3744
850-Mc/s, experimental, KC2XCY, 566
10-kW, Nikolassee, Berlin, 245
100-kW, output stage for, 3742
u.h.f., experimental broadcast to schools, 555
monitoring equipment for, 247
vestigial-sideband system, response to 'sine-squared' step voltage, 1066
video signal, application of autocorrelation theory to, 3122
power density spectrum analysis by autocorrelation, 3121
waveform, display apparatus for, 2745
wire-distribution systems, 1808
specification and testing of, 1755
Test equipment, (See also individual instruments; Television)
cable-fault indicator, 2392
cable-fault locator, pulse-operated, portable, 3361
for c.r.o. display of transistor characteristics, 3053
for f.m. systems, 3664
for group-delay distortion of transmission system, 1076
for harmonic response of linear systems, 3374
insulation tester, electronic, 500-V–10-kV, d.c., 480
microwave, for magnetron production, 778
radar, Type-TF890A, 1445
reference-level, direct-reading, for telephone circuits, 777
S-band, with frequency-sweep generator, 3671
for the TD-2 microwave radio relay system, 3063
Thermistors, characteristics and applications of, 948, 3215
h.f. power measurement with, 1441
manufacture of, 2240
resistance of, effect of pressure on, 342
Thermocouples, for radiation measurements, using semiconducting materials, 3376
Thermometers, sensitive radio receivers as, 2761
Thunderstorms, radio location of, recent developments in, 1020
Time constant, concept of, extension of, 2575
interval recorder, using sawtooth-waveform generator, 152
signals, schedule of transmissions from Observatoire National, Paris, 2744
Timebases, circular, slow-speed, 673
line, single-valve, 2814
negative-feedback, instability in, 2272
pulse-operated, 1630
review of, 1631
sawtooth derivator for c.r.o., 2269
Timers, electronic, 1420
spark-type, 455
ignition-type, for spot-welding machines, 501
photographic-exposure, with compensation for supply-voltage variations, 789
reading in seconds or in cycles, 770
Torque measurement, electrical microdynamometer for, 490
Transducers, $BaTiO_3$, circular, bimorph, sensitivity of, 926
h.f., with wide-angle beam, design of, 3167
crystal, graphical aids in interpreting performance of, 3164
electromechanical, for telemetry, 2412
magnetostrictive, simple method for constants of, 5
Transductors, input- and power-type, for frequencies of 400 c/s and 1·6 kc/s, 3216
single-phase, design of, 1254
3-phase, for magnetic amplifiers, 949
Transformers, a.f., factors concerning use of, 2577
balun, balance measurements on, 3663
double-tuned, unequal-Q, design of, 3499
feeding half-wave rectifier circuit, transient conditions in, 3501
i.f., coupling coefficient of, meter for, 3658
input impedance and transimpedance of, 2578
impedance, modified exponential line as, 3533
for infrared chopped-beam systems, for operation at 10 c/s, 942
production by Technograph etching system, 353
pulse, peaking, design of, 2233
series peaking, design of, 1598
turns index for design of, (A)1250, 3500
using varying-pitch helical windings, 2234
voltage, design of, 1599
Transients, in networks, analysis of, 1247
response of filters and transmission lines, formulae for, 1248
Transistors, (See also Valves, crystal)
characteristics of, c.r.o. display of, 1437
control applications of, 792
equivalent-circuit diagrams for, 3522
field-effect, unipolar, 3445, theory of, 879
filamentary, large current amplification in, 1516
Ge, and Ge rectifier, theory of, 2821
p-n-junction, power, 834
p-n-p-junction, fused-impurity, 876, 877
p-n-p-n-junction, equivalent circuit of, 878
point-contact, base resistance of, effect of electrode spacing on, 882, control of frequency characteristics and stability of, 884, factors in design of, 2487, for frequencies up to 302 Mc/s, 585, mechanism of, 3331
in grounded-collector connection, parameters of, 3518
junction, admittance parameters of, bridges for measurement of at 1 kc/s–1 Mc/s, 3359
bandwidth limit of, 3747
circuit applications of, 3244
effects of space-charge-layer thickness in, 874, (D)3212
equivalent circuits for, and analogy with valves, 644
frequency variation of current gain in, 690
l.f. and m.f. characteristics of, 2489
n-p-n, properties of, 2490, tetrode, for h.f., 677, 1184
p-n, current amplification factor for, 2488, theory of noise in, 871
p-n-p, current gain in, 881
pulse response of, 3514
symmetrical properties of, circuits based on, 2583
noise in, circuit problems of, 643
measurements of, 887
meter for production testing of, 2385
oscillator circuits using, 45
parameters of, temperature variation of, 883
physics of, 265
and analogue type of, 746
point-contact, transient effects in, 2491
Type-A, trigger circuit using, 3516
properties of, and applications of, 1851
and circuits for, 44
review of development and applications of, 873
Si, p-type, measurements on, 2823
point-contact, properties of, 2822
small-signal parameters of, measurement of, 3358
stabilization of amplifier operation of, 688, (C)3248
in switching circuits, 3515
test methods and equipment for, 3053
theory and applications of, 1957, 2289, 2627, 3021, 3444, 3523
transformer circuits for, 1287
use in aircraft equipment, 672
use in f.m. oscillator, 2938
Transistrons, blocking-layer interaction in and fluctuation statistics for, 586
Transmission lines, (See also Cables)
balanced, attenuation measurement for, 467
unscreened measurement of attenuation of, 159
coaxial, charts for probe measurements on, 458
rectangular, characteristic impedance of, 3474
two-dielectric, propagation along, 3185
condition for distortion-free transmission in, 2560, (D)2561
conical-helix, e.m. wave propagation along, 1973
constants of, approximate formulae for, 619
delay, compensated, theory of, 1262
for digital computers, 3650
elastic-solid, diffraction patterns for, 2574
high-characteristic-impedance, for pulses of duration $<1\mu$s, 2257
interdigital, for travelling-wave valves, 2828
low-frequency, design of, (A)1603, 2920
ultrasonic, 2921, magnetostrictive, 2057, vitreous-silica, performance of, 347
exponential, and their radiation loss, 3187
fixed-length, as circuit elements, 1272
helical, for microwave measurements, 779
helical slit, propagation in, 3476
h.f., effect of losses in, 3475
h.v., design of in relation to radio noise level, 927
impedance of, determination by three-point method, 2733
$\lambda/4$, short-circuited, input impedance characteristics of, (D)319
laminated, Clogston-type, theory of, 25, 618, 2562
load impedance for maximum efficiency, 2219
long, input impedance and location of nonuniformities of, 1579
microstrip, and associated components, measurements on, 623, 2214
for kMc/s range, 621, 2212
simplified theory of, 622, 2213
multiconductor, with h.f. TEM waves, analysis of, 26
nonuniform, multiple, theory of, 1581
short, in u.h.f. techniques, 2917
surface-wave, with bends, propagation along, 3473
dielectric-coated, 1906, single-wire, at 10-cm λ, 3186
launching process for, 320
possible applications of, 620
single-wire, theory of, 1580
for 1·7–2·4 kMc/s, 930
uniform, synthesis of, 2880
Transmitters, (See also Television)
broadcasting, a.m., at WNEW, for continuous operation, 3746, 1-MW, 2176
anode-modulated, distortion in, 262
high-power, B.B.C. Third Programme, remote control of, 261

World Radio History

Transmitters, broadcasting, speech-input systems for, 824
s.w., 100-kW, 2819
unattended, B.B.C., monitoring of, 548
communication, h.f., 4-channel, Type HC.100, 3135
1-MW, for 14·5–35 kc/s, for U.S. Navy, 821
harmonic-radiation from output stage of, 2482
h.f., for aerodromes, 3419
magnetron, a.m., injection-locked, measurements on, 1060, 2183
marine, design problems of, 3443
radiotelegraphy, for mercantile-marine vessels, 2818
rounding of signals by use of filters in, 1847
and receivers, for citizens' radio, 2437
R/T, s.s.b., for 4–23-Mc/s 4-channel system, 541
s.s.b., phase-rotation, output analysis and alignment techniques for, 2481
for s.w. radio link, independent-sideband drive unit for, 2175
300- and 400-kc/s, for Palais de Chaillot translation service, 2794
Troposphere. (See also Atmosphere)
refractive index of, abacs for computation of, 1670
measurement of fluctuations and profiles in, 1341
vertical and horizontal gradient over U.S.A., 1991
upper, and lower stratosphere, over southern England, humidity of, 1671
Tuners, automatic, in microwave receivers, 2130
coaxial-cavity, 470–890-Mc/s, 1952
Tuning, automatic, of h.f. generators with varying load, 681
electronic, of r.f. circuits, use of ferrite cores for, 3589

Ultrasonic absorption. See Absorption.
applications, echo-sounding equipment with new indicator, 1092
flaw detection, elimination of parasitic echoes in, 492
fluid-flow measurement 2084
h.f. reciprocating drill for hard brittle materials, 2085
light-diffraction apparatus for determination of elastic constants, 3072
in metallurgy, 2402
in rubber industry, 493
testing of materials, using $BaTiO_3$ oscillator, 1756
tinning of Al, 800, 801
torpedo-depth measurement, 1447, 2401
whale location, 1757
Ultrasonics, cavitation investigations, 1560
energy concentration in, 603
field intensity, in liquids, thermoelectric method of comparison, 3171
probe method of measuring, 2195
field-investigation method based on starch-iodine reaction, 8
interference of beams incident on and reflected by plane wall, 1558
interferometer for measurements in, 1223
in liquids, review of, 1563
in short-range telephony, 1885
in solids, and applications, 1884
measurement of velocity, 1561
transmission through plane absorptive plate immersed in liquid, 2863
velocity, and absorption in dry CO_2-free air, 7
in Ar at pressures up to 950 atm, 1559
Units, and dimensions, of electrical quantities, 86
Ursigrams, European, abbreviated codes for, 2650, 2980, (C)2981

Vacuum gauge, ionization, cylindrical, magnetron-type, 3000
Penning, degassable, 3001, operation of, 2634
pumps, diffusion, working fluids for, 1686
electronic, 2011, 3320
technique, clean-up of He in arc discharge, 3604
getters, Ba, 2321, powdered Zr, quality estimation for, 3034, thorium powder, 2675
ionization method of evacuation, 2011, 3320
production and measurement of pressures down to 10^{-10} mm Hg, 3603
use of membranes in, 110
Valves. (See also Counter tubes; Discharge tubes; Transistors; Transistrons)
amplifier, resistive-wall, 2498, 3147
backward-wave, starting currents in, 3752
beam-deflection, Type E80T, 2843, in multichannel I.G.O. circuits, 2817
characteristics of, effect of filament voltage on, 1866
fine structure of, 3143
cold-cathode, recent developments of, 2501
corona-discharge, voltage-stabilizer, measurements on, 3155
counter, decade, ribbon-beam, 3762
counter and switching, gas-filled, 296
and c.r. tubes, for television receivers, 1521
crystal, diode, Si *p-n*-junction, 905
diode and triode, review of characteristics of, 264
Ge, 1515
Ge-diode, influence of contact and of pulse treatment on, 2179, negative resistance in, 2180, point-contact, transient effects in pulse response of, 872, sealed-in construction, 1849, as video detectors, 2475
junction-type fieldistors, 880
diode, cathode-temperature determination from retarding-field characteristic, 1199
conductance and noise-power spectrum of, 1198
correcte l evaluation of anode current in, 1861
effect of V_f on I_a in, 1194
influence of initial velocities on electron transit time in, 1193
Valves, diode, planar, extension of Llewellyn's transit-time solution, (D)1862, h.f. admittance with retarding field, 290, plasma equations for electron flow in, 1863
with plane inclined electrodes, theoretical investigation of, 2509
saturated, stability of, 2511, subminiature valves operated as, 1197, (D)2512
space-charge smoothing factor for, (A)291, 1196
with W filament, saturation current of, 2513
diode and triode, low-frequency noise in, 1192
double-beam, for amplification at 3 kMc/s, 3146
electrometer, low-frequency noise in measurements of, 1185
electron-stream, influence of wall admittance, 2498
emission current in, approximation to 3/2-power law for finite cathode, 3757
gas-filled, for industrial applications, 295
triode, discharge processes in, 1542
gated-beam, Type-6BN6, as fast coincidence counters, 512
glow-discharge, cold-cathode, inertia effects in, 903
large-current, characteristics of, 3457
voltage-regulator, characteristics of, 591, peak-noise characteristics of, 2516
heaters for, extension of operating-voltage range of, 287
heptode, Type-DK92, in frequency changer for 3·3–30 Mc/s, 813
for industry and research, classification of, 587
klystron, construction, properties, operation and applications of, 596
equations of oscillations of beams in, 3144
floating-drift-tube, investigation of, 1544
gridless, 3-cavity, 5-kW, 1213, 3-cavity, high-power, for λ 10·5 cm, 3161
high-power, a.f.c. of, 2942
power-amplifier, Type-SAL-39, using space-charge focusing, 595
reflex, for cm-wave links, 1546, with coupled resonators, 3160, f.m. distortion in, 1545, oscillation mode and bunching efficiency of, determination of, 3159, Type R5081 for f.m. at cm λ, design of, 1214, 14·5–17·5-kMc/s, design features of, 2853
u.h.f., Type-V42, 15-kW, 1212
magnetron, application of thermodynamics of irreversible processes to, 2847
basic principles of, 1209
conductance measurements on, 157
currents and space charge in, 3764
in cut-off state, effects of h.f. wave in, 594, experimental study of, 1210, space-charge distribution in, 592
for dielectric heating at 915 Mc/s, 2850
early history of, 2851
German, 2852
grid-type, for modulation at u.h.f., 2519
with interdigital circuit, 2187, design of waveguide-loaded resonator for, 2848
inverted and planar, efficiency of, (D)2849
l.v., tunable, Type PAX3, for beacons, 2183
microwave equipment for production testing of, 778
mode interactions in, 593
multicavity, natural oscillations and mode changes in, 1543
multisegment, theory of, 3158, 3458
rising-sun, possibility of generating mm-waves with, 297
single-cavity, 'turbator', 2518
whole-anode, oscillations in, 904
matching of by means of resistors, 3563
oxide-cathode, aged, frequency dependence of mutual conductance of, (A)2838
characteristics of, changes of, 3755
pentode, optimum screen voltage of, 294
Type-C3m, for a.f. and r.f., 589
reliable, specifications for, 270
technique of, 272
reliability of, 271
resnatron, reflex, u.h.f., theory of, 1207
u.h.f., axial-flow, 1208
retarding-field, motion of electrons in, 3157
screen-grid, limiting sensitivity of, 1538
sockets, for industrial equipment, review of, 1860
space-charge-wave, theory of, 1856
spiral-beam, for u.h.f. television modulation, 2188, 2500
subminiature, with filament cathodes, reliability of, 3749
tetrode, 1-kW, u.h.f., 1206
thyratron, applications for switching and control, 902
grid-circuit reliability of, improvement of, 2517
inert-gas, arc drop and deionization time in, 3154
small-signal control of, 3218
for telephone-circuit engineering, 3156
transit-time, influence of plasma oscillation in, 1525
transmission-line, proposals for, 269
transmitting, heat-transfer data for, 2495
high-power, for industrial heating applications, design of, 3759, vapotron, 3451
Swiss developments in production of, 1548
travelling-wave, amplifier, large-signal theory of, 2197, low-noise, 275, 277
characteristics in dispersive region of delay line, 2826
with corrugated rectangular waveguide, 1186
developments in, 1524
electronically tuned, 3454
excitation of e.m. fields by current waves in, 279
experimental verification of theory of, 280
helix-impedance measurement on, 3753

World Radio History

Valves, travelling-wave, helix-type, theory of, **3453**, 10-W, for 15 cm λ measurements on, **2499**
interaction of space-charge waves with electron beam in crossed fields, **1526**
with interdigital delay line, **2828**
long-beam, magnetic electron optics of, **2827**
low-noise, **273**, **(C)2496**
noise measurements on, **3145**
phase distortion in, **1855**
power capacity of, factors affecting, **3751**
recent developments in, **274**
reduction of noise factor in, **3754**
reflex, theory of, **276**
review of, **2183**
space-harmonic, **2831**, 50-kMc/s, **1187**
thermal-velocity-spread effect on noise figure of, **3452**
Type CV2188, for cm-λ radio links, **2829**, construction and operation of, **2830**
triode, amplification factor of, **1537**
amplifier, limiting sensitivity of, **1203**
conventional, u.h.f. oscillations in, **2271**
disk-seal, grounded-grid, circle diagram for input admittance of, **3564**
gas-filled, in pulse amplifiers, **2274**
inherent feedback in, **1865**
low-frequency noise in, measurements of, **1202**
oscillator, limiting frequency of, **1201**, Type-6AF4, for u.h.f. television receivers, **900**
planar, design charts for, **2514**, positive-grid, current division in, **1533**
potential distribution between plane accelerating grid and anode, **1534**
transit-time oscillations in, **(D)1200**
transmitting, u.s.w., Siemens, **1535**, 100-kW, with thoriated-tungsten filaments, **2841**
triple-diode Type-E/U/PABC 80, **1191**
u.h.f., design of, **1536**, Type-Z2103, performance of, **1204**, Type 6AJ4, **1205**
triode and tetrode, for coaxial-cable system, **293**
triode-hexode, Type-ECH42, applications of, **590**
tuning-indicator, Type-DM70, for battery or mains receivers, **3456**
u.h.f., C.F.T.H., for 3-cm radar equipment, **588**
use of Ni in, **2357**
use of Ni-alloys in, **3629**
v.m., coaxial-line, for f.m. radio links, **1211**
theory of, debunching of electron beams in strong magnetic fields, **3459**
voltage-regulator, dynamic characteristics of, **1871**
Vibrations, of air in pipes with internal discontinuities, investigation of, **599**, **2193**
measurement of, **790**, **(D)2400**
nonlinear, iterative method for, **3571**
Voltage, direct, measurement by comparison method, **2726**
measurement of in high-resistance circuit, using single universal meter, **3653**
ratio box, h.v., 1-MΩ, **474**
50-c/s, stabilized, calibrated, as reference standard, **1424**
Voltmeters, using cathode follower and thermocouple, effect of valve nonlinearity in, **1746**
diode-valve, errors in, **780**
rectifier-type, 1–500-V, 30-c/s–300-Mc/s, **167**
valve, direct-voltage, high-resistance, for ±500 V, **2078**
wide-range, using electrometer valve, for ±500 V, **2079**
Volume compression, automatic, electronic, **965**

Wattmeters, a.f., thermocouple-type, **2394**
electronic, for a.c.-network analyser, **3669**
e.s., portable, design and applications of, **1081**
h.f., with dry rectifier, **1752**
microwave, vibration-type, **1442**
torque-type, for 3-cm microwaves, **1082**
Wave propagation, acoustic. See Sound.
dispersion of ultrasonic pulse transmitted through water-filled tube, **2538**
ultrasonic, in viscous liquids, critical λ for, **302**
Wave propagation, e.m., (See also Diffraction; Field strength; Reception; Television; Transmission lines; Waveguides; Waves)
in anisotropic medium, **3393**
across boundary separating regions with different complex permittivity, **3688**
British research with reference to television, survey of, **1109**
cm-λ, fading on 39-mile optical path over sea, **203**
in optical range, **3097**
phenomena on line-of-sight links, **1785**
comparison of c.w. field intensity and back-scatter delay, **808**
diagram for calculating transmitter service range, **2414**
diffraction of, due to earth's curvature, **1776**
tables of functions occurring in theory of, **1777**
in dispersive medium, analysis of, **390**, **1007**
fading, random, theory of, **2120**
scintillation, microwave, frequency of, **3098**
on u.s.w., due to inversion layers, **3695**
field-strength fluctuations, at u.h.f., beyond horizon, **1473**, prediction of diurnal variations of, **1112**, due to turbulence on line-of-sight path, **3394**
ground-wave, l.f., effect of large ground dielectric constant on, **2113**
Wave propagation, e.m., group propagation time, extension of Fermat's principle to, **3592**
along helices, **388**
through highly ionized gases, **3268**
in inhomogeneous medium, **2415**
in inhomogeneous plasmas, theory of, **712**
in ionized gas, **198**
in ionized medium, differential equation for rays in, **1465**
mean velocity of energy in, **196**
simplified treatment of wave equation for, **803**
ionospheric, critical frequencies, for oblique incidence, **2115**, relation to sunspot cycles, **1350**
cross-modulation in, theory of, **3095**
of decametre waves in arctic polar regions, **1783**
disturbance of, relation with geomagnetic activity and solar noise, **3283**
and fluctuation effects, **1105**
forecasts for, C.C.I.R.-U.R.S.I. cooperation in, **3092**, comparison of N.B.S. and Spanish methods, **1107**, comparison of Spanish and C.R.P.L. results, **3689**, comparison of Spanish and other methods, **1773**
over great distances, lateral deflection due to reflection, **520**
gyro-interaction in, solar influence on, **3693**, at vertical incidence, **2111**
h.f. and m.f., attenuation characteristics for and application to field-strength calculations, **2774**
higher-order approximations in, **2108**
limiting polarization of waves reflected from ionosphere, theory of, **1104**
oblique-incidence, over equatorial regions, **805**, characteristics of 9-Mc/s pulses during solar eclipse, **2770**
of plane waves, **2766**
pulse distortion in, **513**
ray-path calculations for, **3093**, **3691**
reflection from vertical and horizontal gradients, **2418**
solution for reflected long waves, **(D)410**, **517**
theoretical group heights of reflection of pulsed 150-kc/s waves, **516**
v.h.f., review of characteristics of, **2422**
at v.l.f., l.f. and m.f., review of, **1781**
at 9·83 Mc/s, fluctuations of azimuth angle, **1774**
l.f., oblique-incidence pulse measurements at 300 kc/s over 1185-km path, **1474**
phase-velocity measurements over 177-km land path, **1782**
magneto-ionic equation for, corrected quasi-transverse approximation to, **514**, physical interpretation of, **515**
magneto-ionic multiple splitting in, **2114**
magneto-ionic theory of, **3392**
magneto-ionic z-component, polarization of, **1775**
matrix analysis of transmission through multilayer dielectric wall, **1668**
microwave, interaction in gas-discharge plasma, **2637**
through multilayered media, **90**
through pair of parallel-wire grids, **3590**
polar blackouts recorded at Kiruna observatory, **3094**
polarization of vertically incident 150-kc/s waves, **806**
reflection, from inhomogeneous medium, **1466**
from varying media, theory of, **2765**
scatter-sounding methods of prediction of h.f. transmissions, **201**
scattered echoes, experiments on, **2776**
scattered waves in, field strength of, **2775**
Sommerfeld's surface wave, existence of, **(D)3391**
nonexistence of, **195**, **3686**
s.w., communication on frequencies exceeding predicted m.u.f. values, **3090**
long-distance, via meteor-trail reflection, **2117**, **2421**
single-hop via F_2 layer, Delhi to Calcutta, **2116**
transmission loss in, **1111**
in transparent periodically stratified medium, **3589**
tropospheric, in duct of nonuniform height, **1471**
N.B.S. research programme on, **2768**
selected references on, **2416**
and wave mechanics, **2112**
u.h.f., graphs for, **2118**
beyond horizon, at 40 Mc/s–4 kMc/s, **1114**
u.s.w., over the Alps, **3397**
in Baltic area, and optical refraction, **521**
and meteorology, **3694**
v.h.f., COZI skip-distance indicator, **3600**
diffraction effects of hills, **3091**
long-distance, multiple bursts of signal in, **2419**
meteorological effects on, **1784**
reduction of transmission loss and fading for long paths over mountainous terrain, **3396**
in relation to television in United Kingdom, **1110**
of very long waves, and wave spectrum of lightning, **802**, **1772**
wave-theory field calculation for total reflection, **1006**
16-kc/s, interpretation of measurements by waveguide theory, **2773**
by oblique reflection from ionosphere during solar flares, **2769**
56-Mc/s, scattering from lower ionosphere, **2119**
85-Mc/s, experimental study of, **2423**
100-Mc/s, correlation with meteorological effects, **2772**
Waveform, (See also Analysis, frequency)
analysis, for harmonics up to twelfth, **1427**
recurrent, high-speed, Type-500 monitor for, **482**
Waveguides, attenuation in and surface roughness of, **1584**
calculation of excitation of, **2563**
with capacitive pins, as microwave λ/4 plate, **(C)2215**

World Radio History

Waveguides, circular-section, excitation of, 2564
for low-loss multimode long-distance transmission, 1585
magic-T units for, 3219
short sections of, measurement of TE_{01} attenuation in, 1068
with TE_{01} wave, susceptance of circular obstacle in, 2565
cylindrical, with coaxial dielectric rod, cut-off frequency of, 2886, propagation in, 2885
containing ferrites, transmission modes in, 1586
transients in, 2887
designation of waves in, with reference to German 1944 Standards, 2217
dielectric, radiation from, 322
dielectric and metal, analysis and comparison of, 28
dielectric-filled, electron beam in, theory of 382
diffraction at plane diaphragms in, 625
disk-loaded, concept and measurement of impedance in, 626
electroplated, attenuation and surface roughness of, 2881
Faraday rotation in, (C)1232
containing ferrites, modes in, 2888
properties and applications of, 931
filled with two or more dielectrics, propagation in, 1907
h.f., relative power-carrying capacity of, (D)27
high-power dummy loads for, 2892
impedance matching by means of discontinuities in, 3477
inhomogeneously filled, calculation of propagation constants for, (D)624
junctions for, symmetrical, scattering matrix of, 66
two-port, graphical analysis of, 3191
parallel-plane, diaphragm-loaded, propagation in, 3189
layered-dielectric, propagation in, 321
propagation in, theory of, 1582
radiation from, visual observation of, 1231
rectangular, diaphragms with slits in, 1583, 2566
with longitudinal conducting membrane, field in, 2882
rectangular and spherical, slot coupling of, 3193
rhombic cross-section, propagation in, 2883
rigid, standard sizes of, U.S. specifications for, 2891
shielded-dielectric-rod, 2218
containing spiral, partly filled with dielectric, theory of, 2884
with thick obstacles, impedance-matching properties of, 3190
transient phenomena in, 2216
Wavelength measurement, by spectrometer and interferometer methods, 2384
Waves, (See also Diffraction; Sound; Transmission lines, surface-wave)
acoustic, concept of energy of, 2860
momentum of, 3165
in viscous medium, forces due to, 2536
a.m., mechanical synthesis of, 469
cm-λ, scattering of by precipitation, 1363
e.m., ionosphere-reflected, chart for, 1469
Waves, e.m., microwave, reflection by metal-plate structures, 389
and photons, relation between, 709
scattering, and attenuation by nonspherical atmospheric particles, 2314, in inhomogeneous atmosphere, 804, 1468, by precipitation, 1362
standing, measurement of high s.w.r. of, 1070
submillimetre, use of Tcherenkov effect for production of, 1970
in tubes, theory of, 3555
velocity of, proposed use of cylindrical surface-wave resonator for determination of, 3355, shoran determination of, 1470
magnetohydrodynamic, in conducting liquids, 1661
generalized formulae for, 2636
in ionized He, demonstration of, 89
longitudinal, 2635
studies of, 1660
space-charge, in electron streams, 2486
ultrasonic, in liquids, demodulation of, 2864, measurement of velocity in, 2859
in solids, velocity of, 1225
visualization of, phase method for, 2865
Welding, electric, measurement of effective values of currents for, 194

Zeeman effect, at microwave frequencies, measurement of, 1318

ERRATA

In "Abstracts and References" throughout the year

Abstract No. 41 Cancel the dagger in the U.D.C. number.
" " 121 In line 4, for 'larger' read 'large'.
" " 384 For '537.533.8' read '537.534.8'.
" " 454 For '621.385.5' read '621.383.5'.
" " 763 In line 9, for '$(f)t$' read '$f(t)$'.
" " 1377 For 'S. T. Kalashnikov' read 'S. G. Kalashnikov'.
" " 1547 For '621.38(061.4)' read '621.38 : 061.4'.
" " 2328 For 'R. Freymann' read 'R. Freymann, R. Rohmer & B. Hagene'.
" " 2576 In line 9, for 'required' read 'described'.
" " 2894 For 'S. K. Dike' read 'S. H. Dike'.
" " 3015 For '537.311.35' read '537.311.33'.
" " 3095 For '3905' read '3095'.
" " 3408 For '621.018.78' read '621.3.018.78'.

U.D.C. Changes

Cyclotron 621 384.611
Getters 621.3.032.461
Pulse 621.3.018.75

LIST OF JOURNALS

A selection of the journals which are regularly scanned is given below, together with the addresses of their publishers or editorial offices and the abbreviations of their titles as used in the Abstracts and References. Applications for copies of any journal should be made to the addresses given.

The full title of each journal is given in bold type and is followed by the address, the abbreviated title being shown within brackets. In a few cases the nature of a journal is indicated, where neither the title nor the address shows it clearly.

Acta physica austriaca, Springer Verlag, Wien I, Mölkerbastei 5, Austria. (*Acta phys. austriaca*)
Acta Polytechnica, Royal Swedish Academy of Engineering Sciences, Stockholm, Sweden. (*Acta polyt., Stockholm*)
Acustica, S. Hirzel Verlag, Gotthardstrasse 6, Zürich, Switzerland. (*Acustica*)
Advances in Physics, Taylor & Francis Ltd, Red Lion Court, Fleet Street, London, E.C.4, England. (*Advances Phys.*)
Akustische Beihefte, S. Hirzel Verlag, Gotthardstrasse 6, Zürich, Switzerland. (*Akust. Beihefte*)
Alta Frequenza, Associazione Elettrotecnica Italiana, Milano (202), Via S. Paolo 10, Italy. (*Alta Frequenza*)
Annalen der Physik, J. A. Barth, Leipzig C1, Salomonstrasse 18B, Germany. (*Ann. Phys., Lpz.*)
Annales de Géophysique, Service des Publications du C.N.R.S., 45 rue d'Ulm, Paris 5e, France. (*Ann. Géophys.*)
Annales de Physique, Masson & Cie, 120 Boulevard Saint-Germain, Paris 6e, France. (*Ann. Phys., Paris*)
Annales de Radioélectricité, 10 rue Carducci, Paris 19e, France. (*Ann. Radioélect.*)
Annales des Télécommunications, 3 & 5 Boulevard Pasteur, Paris 15e, France. (*Ann. Télécommun.*)
Annali di Geofisica, Istituto Nazionale di Geofisica, Città universitaria, Roma, Italy. (*Ann. Geofis.*)
Applied Scientific Research, Martinus Nijhoff, Lange Voorhout 9, The Hague, Netherlands. (*Appl. sci. Res.*)
Archiv der elektrischen Übertragung, S. Hirzel Verlag, Stuttgart, Germany. (*Arch. elekt. Übertragung*)
Archiv für Elektrotechnik, Springer Verlag, Heidelberg, Neuenheimer Landstrasse 24, Germany. (*Arch. Elektrotech.*)
Archiv für Meteorologie Geophysik und Bioklimatologie, Series A, Springer Verlag, Wien I, Mölkerbastei 5, Austria. (*Arch. Met., Wien*)
Archiv für technisches Messen, R. Oldenbourg Verlag, München, Lotzbeckstrasse 2b, Germany (*Arch. tech. Messen*)
Arkiv för Fysik, published for Royal Swedish Academy of Sciences by Almqvist & Wiksells Boktryckeri A.B., Stockholm, Sweden. (*Ark. Fys.*)
A.T.E. Journal (incorporating Strowger Journal), Automatic Telephone & Electric Co., Strowger Works, Liverpool 7, England. (*A.T.E. J.*)
Audio Engineering, Radio Magazines Inc., 10 McGovern Avenue, Lancaster, Pa., U.S.A. (*Audio Engng, N.Y.*)
Australian Journal of Applied Science, Commonwealth Scientific and Industrial Research Organization, 314 Albert Street, East Melbourne C2, Australia. (*Aust. J. appl. Sci.*)
Australian Journal of Physics (formerly **Australian Journal of Scientific Research Series A**), Commonwealth Scientific and Industrial Research Organization, 314 Albert Street, East Melbourne C2, Australia. (*Aust. J. Phys.*)
A.W.A. Technical Review, Amalgamated Wireless (Australasia) Ltd, Sydney, Australia. (*A.W.A. tech. Rev.*)

B.B.C. Quarterly, British Broadcasting Corporation, 35 Marylebone High Street, London, W.1, England. (*B.B.C. Quart.*)
Beama Journal, British Electrical and Allied Manufacturers' Association, 36 Kingsway, London, W.C.2, England. (*Beama J.*)

World Radio History

Bell Laboratories Record, 463 West Street, New York 14, N.Y., U.S.A. (*Bell Lab. Rec.*)
Bell System Technical Journal, American Telephone and Telegraph Company, 195 Broadway, New York 7, N.Y., U.S.A. (*Bell Syst. tech. J.*)
British Journal of Applied Physics, 47 Belgrave Square, London, S.W.1, England. (*Brit. J. appl. Phys.*)
Brown Boveri Review, Baden, Switzerland. (*Brown Boveri Rev.*)
Bulletin de l'Académie des Sciences de l'U.R.S.S., (*a*) série physique, (*b*) série géophysique, (*c*) classe sciences techniques, Academy of Sciences, Moscow, U.S.S.R. (In Russian.) (*Bull. Acad. Sci., U.R.S.S., (a) sér. phys., (b) sér. géophys. (c) tech. Sci.*)
Bulletin de l'Association suisse des Électriciens, S.A. Fachschriften-Verlag and Buchdruckerei, Stauffacherquai 36–40, Zürich 4, Switzerland. (*Bull. schweiz. elektrotech. Ver.*)
Bulletin de la Société française des Électriciens, 55 Quai des Grands-Augustins, Paris 6e, France. (*Bull. Soc. franç. Élect.*)

Câbles et Transmission, Sotelec, 16 rue de la Baume, Paris 8e, France. (*Câbles & Transm.*)
Canadian Journal of Physics, National Research Council, Ottawa, Canada. (*Canad. J. Phys.*)
Chalmers tekniska Högskolas Handlingar, N. J. Gumperts Förlag, Göteborg, Sweden. (*Chalmers tek. Högsk. Handl.*)
Communication Engineering, The Publishing House, Great Barrington, Mass., U.S.A. (*Commun. Engng*)
Communication News, Philips Telecommunications Industries, Hilversum, Netherlands. (*Commun. News*)
Communications on Pure and Applied Mathematics, Interscience Publishers Inc., 250 Fifth Avenue, New York 1, N.Y., U.S.A. (*Commun. pure appl. Math.*)
Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, Gauthier-Villars, 55 Quai des Grands-Augustins, Paris 6e, France. (*C.R. Acad. Sci., Paris*)
Comptes Rendus (Doklady) de l'Académie des Sciences de l'U.R.S.S., Academy of Sciences, Moscow, U.S.S.R. (In Russian.) (*C.R. Acad. Sci. U.R.S.S.*)

Electrical Communication, International Telephone and Telegraph Corporation, 67 Broad Street, New York 4, N.Y., U.S.A. (*Elect. Commun.*)
Electrical Engineering, Journal of the American Institute of Electrical Engineers, 500 Fifth Avenue, New York 36, N.Y., U.S.A. (*Elect. Engng, N.Y.*)
Electrical Journal (formerly **Electrician**), Bouverie House, 154 Fleet Street, London, E.C.4, England. (*Elect. J.*)
Electrical Manufacturing, 1250 Sixth Avenue, New York 20, N.Y., U.S.A. (*Elect. Mfg*)
Electrical Times, Sardinia House, Sardinia Street, London, W.C.2, England. (*Elect. Times*)
Electronic Application Bulletin, N.V. Philips Gloeilampenfabrieken, Eindhoven, Netherlands. (*Electronic Applic. Bull.*)
Electronic Engineering, 28 Essex Street, London, W.C.2, England. (*Electronic Engng*)
Electronics, 99–129 North Broadway, Albany 1, N.Y., U.S.A. (*Electronics*)
Elektrotechnik und Maschinenbau, Journal of the Elektrotechnischer Verein Österreichs, Springer Verlag, Wien I, Mölkerbastei 5, Austria. (*Elektrotech. u. Maschinenb.*)
Elektrotechnische Zeitschrift, Edition A & B, VDE-Verlag G.m.b.H., Frankfurt/Main, Osthafenplatz 6, Germany. (*Elektrotech. Z.*)
Endeavour, Imperial Chemical Industries, Millbank, London, S.W.1, England. (*Endeavour*)
Engineer, 28 Essex Street, London, W.C.2, England. (*Engineer, Lond.*)
Engineering, 35 & 36 Bedford Street, London, W.C.2, England. (*Engineering, Lond.*)
Ericsson Review, Stockholm 32, Sweden. (*Ericsson Rev.*)

Fernmeldetechnische Zeitschrift, Vieweg & Sohn, Braunschweig, Burgplatz 1, Germany. (*Fernmeldetech. Z.*)
Frequenz, Schiele & Schön, Berlin, S.W.29, Boppstrasse 10, Germany. (*Frequenz*)
Funk und Ton, Verlag für Radio-Foto-Kinotechnik G.m.b.H., Berlin-Borsigwalde, Eichborndamm 141–167, Germany. (*Funk u. Ton*)

G.E.C. Journal, General Electric Company, Magnet House, Kingsway, London, W.C.2, England. (*G.E.C. J.*)
G.E.C. Telecommunications, General Electric Company Ltd, Coventry, England. (*G.E.C. Telecommun.*)
General Electric Review, General Electric Company, 1 River Road, Schenectady 5, N.Y., U.S.A. (*Gen. Elect. Rev.*)
General Radio Experimenter, General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass., U.S.A. (*Gen. Radio Exp.*)

Helvetica Physica Acta, Journal of the Société suisse de Physique, Éditions Birkhäuser, Bâle, Switzerland. (*Helv. phys. Acta*)
HF, 55 rue Defacqz, Brussels, Belgium. (*HF, Brussels*)

Indian Journal of Physics (and Proceedings of the Indian Association for the Cultivation of Science), 210 Bowbazer Street, Calcutta, India. (*Indian J. Phys.*)

Journal of the Acoustical Society of America, American Institute of Physics, 57 East 55th Street, New York 22, N.Y., U.S.A. (*J. acoust. Soc. Amer.*)
Journal of Applied Physics, American Institute of Physics, 57 East 55th Street, New York 22, N.Y., U.S.A. (*J. appl. Phys.*)
Journal of Atmospheric and Terrestrial Physics, Pergamon Press Ltd, 242 Marylebone Road, London, N.W.1, England. (*J. atmos. terr. Phys.*)
Journal of the Audio Engineering Society, P.O. Box 12, Old Chelsea Station, New York 11, N.Y., U.S.A. (*J. audio Engng Soc.*)
Journal of the British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1, England. (*J. Brit. Instn Radio Engrs*)
Journal of the Franklin Institute, Prince and Lemon Streets, Lancaster, Pa, U.S.A. (*J. Franklin Inst.*)
Journal of Geophysical Research, 5241 Broad Branch Road, N.W., Washington 15, D.C., U.S.A. (*J. geophys. Res.*)
Journal of the Indian Institute of Science, Indian Institute of Science, Bangalore 3, India. (*J. Indian Inst. Sci.*)
Journal of the Institute of Navigation, John Murray Ltd, 50 Albemarle Street, London, W.1, England. (*J. Inst. Nav.*)
Journal of the Institution of Engineers, Australia, Science House, Gloucester & Essex Streets, Sydney, Australia. (*J. Instn Engrs, Aust.*)
Journal of Mathematics and Physics, Massachusetts Institute of Technology, Cambridge 39, Mass., U.S.A. (*J. Math. Phys.*)
Journal of the Optical Society of America, American Institute of Physics, 57 East 55th Street, New York 22, N.Y., U.S.A. (*J. opt. Soc. Amer.*)
Journal of the Physical Society of Japan, Maruzen Publishing Co., P.O. Box 605 Central, Tokyo, Japan. (*J. phys. Soc. Japan*)
Journal de Physique et le Radium, 12 place Henri-Bergson, Paris 8e, France. (*J. Phys. Radium*)
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Journal of Scientific Instruments, 47 Belgrave Square, London, S.W.1, England. (*J. sci. Instrum.*)
Journal of the Society of Motion Picture and Television Engineers, 40 West 40th Street, New York 18, N.Y., U.S.A. (*J. Soc. Mot. Pict. Televis. Engrs*)
Journal of the Television Society, 164 Shaftesbury Avenue, London, W.C.2, England. (*J. Televis. Soc.*)

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Metal Industry, Louis Cassier Company Ltd, Dorset House, Stamford Street, London, S.E.1, England. (*Metal Ind., Lond.*)
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Metallurgia, 31 King Street West, Manchester 3, England. (*Metallurgia, Manchr*)
Meteorological Magazine, His Majesty's Stationery Office, York House, Kingsway, London, W.C.2, England. (*Met. Mag., Lond.*)
Microtecnic, 23 Avenue de la Gare, Lausanne, Switzerland. (*Microtecnic*)
Modern Plastics, Breskin Publications, Emmett Street, Bristol, Conn., U.S.A. (*Mod. Plast.*)
Monthly Notices of the Royal Astronomical Society, Burlington House, London, W.1, England. (*Mon. Not. R. astr. Soc.*)

Nachrichten Technik, V.E.B. Verlag Technik, Berlin N.W.7, Unter den Linden 12, Germany. (*NachrTech.*)
Nature, Macmillan & Co. Ltd, St. Martin's Street, London, W.C.2, England. (*Nature, Lond.*)
Naturwissenschaften, Springer Verlag, Heidelberg, Neuenheimer Landstrasse 24, Germany. (*Naturwissenschaften*)
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Observatory, Royal Observatory, Herstmonceux Castle, Hailsham, Sussex, England. (*Observatory*)
Onde électrique, 40 rue de Seine, Paris 6e, France. (*Onde élect.*)
Optik, Wissenschaftliche Verlagsgesellschaft, Stuttgart 1, Postfach 40, Germany. (*Optik, Stuttgart*)
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Philips Research Reports, N.V. Philips Gloeilampenfabrieken, Eindhoven, Netherlands. (*Philips Res. Rep.*)
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Revue générale de l'Électricité, 12 place Henri Bergson, Paris 8e, France. (*Rev. gén. Elect.*)

Revue d'Optique, 3 & 5 Boulevard Pasteur, Paris 15e, France. (*Rev. d'Optique*)

Revue scientifique, 4 rue Pomereu, Paris 16e, France. (*Rev. sci., Paris*)

Revue technique Compagnie française Thomson-Houston, 173 Boulevard Haussmann, Paris, France. (*Rev. tech. Comp. franç. Thomson-Houston*)

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R.S.G.B. Bulletin, New Ruskin House, Little Russell Street, London, W.C.1, England. (*R.S.G.B. Bull.*)

Schweizer Archiv für angewandte Wissenschaft und Technik, Buchdruckerei Vogt-Schild, Solothurn, Switzerland. (*Schweiz. Arch. angew. Wiss. Tech.*)

Science Reports of the Research Institutes Tohoku University, Series B, Tohoku University, Sendai, Japan. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*)

Scientific Monthly, 10 McGovern Avenue, Lancaster, Pa, U.S.A. (*Sci. Mon.*)

Sylvania Technologist, Lawrence Street, Flushing, N.Y., U.S.A. (*Sylvania Technologist*)

Technical News Bulletin of the National Bureau of Standards, U.S. Government Printing Office, Washington 25, D.C., U.S.A. (*Tech. News Bull. nat. Bur. Stand.*)

Technische Hausmitteilungen des Nordwestdeutschen Rundfunks, Nordwestdeutscher Rundfunk, Hamburg 13, Rothenbaumchaussee 132, Germany. (*Tech. Hausmitt. NordwDtsch. Rdfunks*)

Technische Mitteilungen, Journal of the Swiss Post Office, Direction générale PTT, Berne, Speichergasse 6, Switzerland. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*)

Tele-Tech, 480 Lexington Avenue, New York 17, N.Y., U.S.A. (*Tele-Tech*)

Telefunken Zeitung, Telefunken G.m.b.H., Berlin S.W.61, Mehringdamm 32–34, Germany. (*Telefunken Ztg*)

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Tellus, Lindhagensgatan 124, Stockholm, Sweden. (*Tellus*)

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Toute la Radio, 9 rue Jacob, Paris 6e, France. (*Toute la Radio*)

Transactions of the American Geophysical Union, 1530 P Street, N.W., Washington 5, D.C., U.S.A. (*Trans. Amer. geophys. Union*)

Transactions of the American Institute of Electrical Engineers, 33 West 39th Street, New York 18, N.Y., U.S.A. (*Trans. Amer. Inst. elect. Engrs*)

Transactions of the Institute of Radio Engineers, 1 East 79th Street, New York 21, N.Y., U.S.A. (*Trans. Inst. Radio Engrs*)

TSF et TV, 40 rue de Seine, Paris 6e, France. (*TSF et TV*)

Le Vide, Journal of the Société française des Ingénieurs Techniciens du Vide, 44 rue de Rennes, Paris 6e, France. (*Le Vide*)

Weather, 49 Cromwell Road, London, S.W.7, England. (*Weather*)

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Capacity in µF	Peak Working Volts	Dimensions in inches		T.C.C. Type Number
		Length	Diameter	
6	3	.64	.18	CE68AA
8	6	.71	.2	CE69A
2	12	.64	.18	CE68B
4	12	.71	.2	CE69B
*8	15	.75	.26	CE67B
1	25	.64	.18	CE68C
2	25	.71	.2	CE69C
.5	50	.64	.18	CE68D
1	50	.71	.2	CE69D

* This condenser can only be supplied with wire terminations both ends.

T.C.C *Patent Nos. 578 487, 578 569, 587 072.*

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Cap μF	Peak Working Volts at 70°C.	Max. R.M.S. Current at 50/c s (mA)	Dimensions (inches) L.	D.	List Number	Inter-Service Cat. Number
TYPE L31/1. PATTERN CE4. CLASS HI						
50	25	70	1 1/4	5/8	JB 53AKZ	Z145512
100	25	100	1 3/4	5/8	JB 54KZ	Z145514
1000	25	600	3	1	JB 57KZ	Z145520
25	50	60	1 1/4	5/8	JB102BKZ	Z145508
50	50	100	1 3/4	5/8	JB103KZ	Z145513
500	50	450	3	1	JB106AKZ	Z145519
8	150	60	1 1/4	5/8	JB153BKZ	Z145502
16	150	90	1 3/4	5/8	JB154KZ	Z145505
32	150	160	1 3/4	3/4	JB181KZ	Z145509
8	350	75	1 3/4	5/8	JB403KZ	Z145503
16	350	120	1 3/4	3/4	JB405KZ	Z145506
32	350	225	2	1	JB407AKZ	Z145510
4	450	50	1 3/4	5/8	JB552KZ	Z145501
8	450	100	1 3/4	5/8	JB553BKZ	Z145504
16	450	175	2	1	JB554AKZ	Z145507
32	450	275	3	1	JB555AKZ	Z145511
TYPE L32/1. PATTERN CE5 CLASS HI						
3000	25	1100	4 1/2	1 3/8	KB 62KZ	Z145557
1500	50	1000	4 1/2	1 3/8	KB111KZ	Z145555
60	350	350	2	1 3/8	KB430KZ	Z145552
100	350	450	3	1 3/8	KB411KZ	Z145554
32	450	275	3	1	KB555BKZ	Z145551
60	450	450	3	1 3/8	KB581KZ	Z145553
TYPE L32/3. PATTERN CE6. CLASS HI						
32+32	350	200	2	1 3/8	KB417KZ	Z145601
60+100	350	400	4 1/2	1 3/8	KB420KZ	Z145603
60+250	350	400	4 1/2	1 3/4	KB422KZ	Z145605
100+200	350	550	4 1/2	1 3/4	KB423KZ	Z145606
32+32	450	300	3	1 3/8	KB564AKZ	Z145602
60+100	450	550	4 1/2	1 3/4	KB565KZ	Z145604

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